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Bulletin volcanologique

ORGANE DE

l'Association de Volcanologie

de l'Union géodésique et géophysique internationale

Publié par le Secrétaire général

FRANCESCO SIGNORE

Série II — Tome VIII

B. V.

NAPOLI
Stabilimento Tipografico Francesco Giannini & Figli
Via Cisterna dell'Olio
1949

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BULLETIN VOLCANOLOGIQUE

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de l'Union géodésique et géophysique internationale.

Série II - Tome VIII - 1949

CONDITIONS DE PUBLICATION

1. **Commission de Publication** — La Commission de Publication est constituée par le Comité exécutif de l'Association de Volcanologie de l' Union géodésique et géophysique internationale:

Élections d' Oslo, 1948. Président: Prof. B. G. ESCHER (Hollande); V. Présidents: Dr. A. G. MACGREGOR (Angleterre ; Prof. NIELS NIELSEN (Danemark); Prof. HOWEL WILLIAMS (États Unis); Prof. L. GLANGEAUD (France); Secrét. général: Prof. F. SIGNORE (Italie).

2. **Correspondance** — Pour toute communication relative au Secrétariat général de l'Association internationale de Volcanologie et à la rédaction adresser: Prof. F. SIGNORE, Via Tasso, 199. Napoli - (Italie).

3. **Insertions** — Seuls sont insérés, s'il y a lieu, les articles ayant pour auteurs les Membres des Comités nationaux et des Sections volcanologiques et les Volcanologistes délégués officiels aux Assemblées générales de l' Union, *ou les articles d'autres présentés par ces personnalités.*

Les opinions et théories émises n'engagent que leurs auteurs.

Les textes adressés au Secrétaire doivent être *dactylographiés,* au recto seulement, *sous leur forme définitive,* les figures bien dessinées, de preference sur carton blanc du type bristol, prêtes à être reproduites par clichage typographique. Il est avantageux de les faire dessiner plus grandes qu'elles ne doivent l'être dans le Bulletin.

Les originaux des articles et dessins ne sont pas rendus.

4. **Bibliographie** — Toute publication adressée au Secrétaire fera l'objet d'un compte rendu sommaire analytique (non critique). Les auteurs sont priés de joindre eux-mêmes ce compte rendu à la publication, en lui donnant une étendue proportionnée a l'importance de celle-ci.

(Voir la suite à p. 3 de la couverture)

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1949

Pour toute communication relative au Secrétariat général de l'Association internationale de Volcanologie, adresser: Prof. **FRANCESCO SIGNORE**,

Via Tasso, 199 - Napoli - Italie.

Téléph. 16723

Huitième Assemblée générale de l'Union Géodésique et Géophysique internationale à Oslo

17-28 août 1948

Procès-verbaux de l'Association de Volcanologie

rédigés par le Prof. Doct. FRANCESCO SIGNORE
Secrétaire général de l'Association

Dans la VIIme Assemblée générale de l'U.G.G.I., qui eut lieu à Washington, septembre 1939, les délégués européens ne purent être présents aux séances, à cause de la guerre; par conséquent les Associations se limitèrent à traiter les questions scientifiques, en renvoyant à la prochaine assemblée générale les élections des membres des Bureaux.

Le Bureau de l'Association de Volcanologie resta constitué par le Président, Prof. Dr. A. MICHEL - LÉVY (France), le Secrétaire général, Prof. Dr. F. SIGNORE (Italie), les Vice-Présidents, Prof. Dr. B. G. ESCHER (Hollande), Dr. T. JAGGAR (États-Unis), Dr. E. RICHEY (Grande-Bretagne).

Pendant la guerre, jusqu'à la cessation des hostilités, fonctionna comme Président par interim le Dr. RICHEY; après la guerre le Prof. MICHEL-LÉVY informa que pour son état de santé il aurait été absent à la Réunion d'Oslo; fut alors chargé de la Présidence le Prof. ESCHER.

Le Bureau a été représenté à l'Assemblée d'Oslo par le Président, le Secrétaire général et le Vice-Président Dr. RICHEY. Le Vice-Président Dr. JAGGAR pria le Secrétaire général de vouloir porter son adhésion, en exprimant son regret de ne pouvoir être présent.

Aux séances ont pris part:

Canada: HANSON G., WILSON J. T.

Danemark: NIELSEN N., SESTOFT I.

Espagne: ROMANA A.

États-Unis: ADAMS L. H., FIELD R. M., GIBSON R. E., PIGGOT C. S., RUSSEL R. D., Madame RUSSEL, SMITH W. E..

France : DAUVILLIER A., GLANGEAUD L., GOGUEL J. M., ROTHÉ J. P., TELLIER E., Madame TELLIER.
Grande-Bretagne : RICHEY J. E.
Inde : WADIA D. N.
Islande : THORARINSSON S.
Italie : SIGNORE F., Madame SIGNORE.
Hollande : ESCHER B. G., MEINESZ F. A.
Norvège : WERENSKIOLD W., DONS J. A.
Nouvelle Zélande : MARSDEN E.
Sud Afrique : KENT L. E.
Suisse : OULIANOFF N., RITTMANN A.

Le Touring Club Italien (T.C.I.) a envoyé son adhésion.

Le 15 août le Secrétaire général a pris conctact avec le Comité ordonnateur norvégien et le 16 le Secrétariat a commencé à fonctionner.

Le Président Prof. Dr. ESCHER, accompagné parfois par le Secrétaire général Prof. Dr. SIGNORE, a pris part active aux séances du Conseil de l'Union, de la Commission de Finance et du Comité Exécutif, en soutenant les intérêts de l'Association.

1e Séance

(20 août, de 15h45m à 17h)

Le Président Prof. ESCHER remercie le Comité norvégien pour le bon accueil fait aux congressistes et commence son discours présidentiel :

« *Sur l'origine de la forme asymétrique de la surface de la terre et ses conséquences sur le volcanisme de la terre et de la lune* ».

La conférence, accompagnée par nombreuses et très intéressantes projections, est vivement applaudie.

2e Séance

(21 août, de 10h à 12h30m)

Préside le Prof. Dr. ESCHER.

Le Secrétaire général Prof. SIGNORE lit son

Rapport sur l'activité scientifique et financière de l'Association:

Messieurs,

En commençant mon rapport, ma pensée s'adresse à la mémoire du Professeur LACROIX, premier Président , et du Professeur MALLADRA, premier Secrétaire de notre Association, qui sont morts respectivement en 1948 et en 1945.

J'invite l'Assemblée avant tout à envoyer son hommage au Professeur MICHEL-LÉVY, qui, à cause de son état de santé, n'a pu prendre part à notre réunion.

Je salue le Professeur ESCHER, qui a voulu gentillement se charger de la fonction de Président. Je remercie enfin le Vice-Président Dr. RICHEY, Président par interim pendant la guerre, pour l'intérêt qu'il m'a montré et les aides qu'il m'a données, aussitôt que nous pûmes nous mettre en relations, et je remercie aussi tous les collègues, officiers des armées alliées, qui, en passant par Naples, ont voulu me rendre visite.

En 1940, lorsque la guerre éclata en Italie, le Bureau avait commencé la publication des volumes VI et VII du Bulletin Volcanologique, qui fut terminée en 1941. Les volumes, qui ne purent être envoyés, furent gardés dans un abris à l'Imprimerie Giannini et heureusement furent épargnés par les bombardements aériens. Lorsque la publication du Bulletin Volcanologique fut terminée, l'activité du Bureau se réduisit beaucoup.

En 1943, avec l'entrée à Naples des troupes alliées, les fonds furent bloqués et seulement en 1945 ils furent remis à ma disposition. Dans cette même époque l'Imprimerie Giannini fut occupée par le Commandement anglais, et par conséquent on ne pu plus y accéder. C'est avec l'aide du Dr. RICHEY auprès des autorités d'occupation et par l'intermédiaire du Consulat anglais à Naples, que je pus envoyer en Angleterre quelques copies des volumes VI et VII, que le Dr. RICHEY distribua aux différentes nations. L'Imprimerie Giannini fut déréquisitionnée vers la fin de 1946, mais les difficultés d'envoyer les publications à l'étranger augmentèrent tellement que je décidai d'entreprendre des relations avec les Ambassades des nations

qui avaient repris leurs relations diplomatiques avec l'Italie, pour envoyer les bulletins et les extraits par le service diplomatique, mais l'Ambassade d'Angleterre seulement accepta ma proposition. Vous me pardonnerez, chers collègues, tout ces détails, que je vous donne seulement pour justifier l'involontaire retard apporté dans la distribution du dernier bulletin. J'ajoute simplement que l'expédition est presque terminée. L'Allemagne et le Japon seulement n'ont pas reçu le bulletin. A mon retour à Naples, j'essayerai de completer l'envoi des extraits.

En 1946-47 a été publiée la carte des volcans actifs du monde, carte des Professeurs KENNEDY et RICHEY, qui a aussi été expédiée comme appendice des volumes VI et VII.

Je souhaite que les relations internationales deviennent au plus tôt stables et cordiales pour que notre Association puisse reprendre complètement son activité.

Beaucoup de recherches attendent d'être reprises en collaboration avec les géologues, les géophysiciens et les géochimistes de tous les pays. Nous devons inciter des recherches sur la composition et la ionisation des gaz magmatiques, sur les phénomènes lumineux, sur les courants telluriques, sur la radioactivité des materiaux déjectés, sur la pesanteur, etc. et commencer surtout la publication du catalogue des volcans actifs du monde.

L'Association avec les épargnes effectuées, avec les nouveaux fonds qui sont mis à sa disposition et avec l'aide de l'U.N.E.-S.C.O., espère pouvoir réaliser ce programme et aider aussi les différents collaborateurs.

De ma part, j'ai envoyé mon avis au Secrétaire général de l'Union, le Dr. STAGG, qu'aucune limite devra être établie pour la somme des économies; chaque Association devra s'administrer elle même. Le président et le secrétaire de chaque Association doivent, à mon avis, être les responsables directes.

Messieurs, je vous présente les comptes de l'Association, avec tous les documents, commençant en 1940 et se terminant en 1947. Je vous prie de choisir une commission pour reviser les comptes. Je suis heureux de pouvoir vous dire que au 31 Décembre 1947 le credit de notre Association était:

£. 2004 dans le compte en livres sterling à Southampton et 189.346 Lires dans le compte à Naples.

Depuis le 1936 jusqu'au 1947 le Bureau a publié 7 volumes et un appendice, en acceptant les mémoires sans limitation du nombre des pages, des tables etc. et en concédant aux auteurs 100 extraits.

Pour l'avenir, je vous souhaite la continuation d'un travail fructueux.

L'Assemblée après avoir exprimé son approbation au Secrétaire général nomme une Commission pour la revision des comptes. La Commission résulte composée par MM. GLANGEAUD et RITTMANN.

Le Prof. ESCHER ensuite lit la lettre suivante du Prof. MICHEL-LÉVY :

« Cher Prof. Dr. ESCHER,

À quelques jours de la réunion prochaine de l'Association internationale de Volcanologie, je viens vous demander de ne pas m'oublier auprès de nos Collègues du Bureau et de l'Association toute entière et d'excuser mon absence à laquelle m'oblige mon état de santé.

Dites leur combien je leur suis reconnaissant de leur confiance depuis l'époque déjà lointaine où ils m'avaient nommé Président à l'Assemblée d'Édimbourg, en 1936, puis après le maintien à ce poste, à Washington, en 1939. Il a fallu les grands désordres résultant de la guerre mondiale pour que je ne quitte cette présidence, habituellement triennale, qu'en 1948, soit 12 ans plus tard. Quelles longues années de paralyse scientifique entre temps ! Des activités très heureuses du Dr. RICHEY, d'utiles conseils du Dr. J. A. FLEMING, ont permis de faire revenir à la vie notre Association aux premiers jours de l'après-guerre.

Je forme le voeu très ardent pour que notre Association retrouvant les concours actifs de nombreux savants vulcanologues de tous pays reprenne les travaux avec un lustre rénouvelé.

Catalogue des Volcans en activité ou éteints, recherches sur les phénomènes explosifs et tous ceux de physique et de chimie nouvelle, à la bouche des volcans actifs etc..., les problèmes à traiter en commun ne manquent pas... et je souhaite que les

moyens matériels ne soient pas trop parcimonieusement mesurés pour l'aide aux savants et les publications du Bureau.

En vous remerciant à nouveau, je vous prie d'agréer cher Professeur ESCHER l'expression de mes sentiments très distingués et les meilleurs.

A. MICHEL-LÉVY »

Le Président propose d'envoyer au Prof. MICHEL-LÉVY un télégramme de regret pour son absence et de profond remerciement pour son travail si fructueux pour l'Association. L'Assemblée approuve à l'unanimité.

Le Président invite le Prof. GLANGEAUD à exposer sa relation :

« *Établissement de cartes paléographiques des anciens volcans* ».

Le travail est illustré par de belles photographies, des esquisses et des cartes.

Le Président complimente le Prof. GLANGEAUD sur son intéressant mémoire. À la discussion qui suit prennent part MM. ESCHER, RICHEY, RITTMANN, SIGNORE.

L'Assemblée décide qu'on institue un office provisoire à Besançon sous la direction du Prof. GLANGEAUD pour organiser les premières recherches.

Parle enfin le Prof. Dr. WILSON du Canada :

« In Canada there is negligible vulcanism at present, but of course much evidence of former volcanoes. If this Association were to be limited to the study of active vulcanism, Canada could take little part. We would therefore welcome the inclusion of former vulcanism.

In addition we are making extensive studies of earth temperature, conductivity and heat flow and of the radioactivity present in ordinary rocks. At University of Toronto we hope this year to publish studies of the heat flow made to a depth of 7000' (2300 metres) in 3 Canadian mining areas. We also have made the determinations of the radioactive content and rate of heat generation in 6000 rocks from North America. It is clear that this radioactive heat is sufficient to explain the origin of volcanism and magmas.

In the Canadian Shield it is clear that the arrangement of some basic intrusives some of which produced volcanoes in late Precambrian time is connected with large faults and with belts of gravity anomalies.

Since Geothermometry and Radioactivity are clearly part of geophysics and have at present no home in the U.G.G.I. I would welcome the espansion of the Association of Volcanology to include these studies and perhaps embrace the whole study of volcanism and its place in the growth of mountains and continents ».

Le Prof. SIGNORE s'associe et observe que l'Association de Volcanologie, comme il a exposé dans une relation au Conseil International des Unions Scientifiques à Bruxelles, 1934 (Bulletin Volcanologique Série I, N.os 27 à 30), a toujours soutenu l'importance des recherches de radioactivité et du degré géothermique et la nécessité qu'elles soient publiées.

(21 août, de 14^h45^m à 19^h)

Les membres de l'Association sous la guide du Prof. Dr. WERENSKIOLD, directeur de l'Institut de Géologie de l'Université d'Oslo, et du Can. mag. J. A. DONS, se rendent en excursion à la « Cauldron » de Baerum.

À la fin de l'excursion le Président remercie de la part de tous les présents MM. WERENSKIOLD et DONS pour leur savante illustration.

(22 août, de 7^h30^m à 24^h)

Excursion à Lillehammer et dans les montagnes environnantes, sous la guide du Prof. Dr. WERENSKIOLD.

3e Séance

(23 août, de 10^h à 13^h)

Président le Prof. ESCHER.

Le Prof. GLANGEAUD lit sa communication :

« *Évolution intracrustale des volcans complexes* ».

Le Prof. DAUVILLIER demande à M. GLANGEAUD quelle est, d'après lui, la cause des intrusions basaltiques qui sont, selon

sa théorie, l'origine des phénomènes exposés. Il pose aussi la question de l'importance du rôle de la vapeur d'eau hypercritique dans les transports atomiques, rôle mis en évidence par diverses expériences récentes.

Le Dr. GOGUEL observe :

« Les chronodiagrammes présentés par l'auteur montrent d'une façon saisissante l'évolution des types de laves, depuis les deux extrêmes jusqu'aux types intermédiaires ; il serait d'un grand intérêt de les completer par d'autres diagrammes, relatifs à chacun des éléments analysés, afin de rechercher dans quelle mesure les types intermédiaires diffèrent de ce qu'aurait donné un simple mélange.

Parmi les phénomènes physiques auxquels l'auteur se réfère, certains feront encore l'objet de discussion de la part des physiciens. C'est ainsi que la variation de la viscosité avec la pression n'est connue que par les corps simples et les liquides organiques. On ignore totalement comment les composants volatifs du magma pourraient modifier sa valeur.

L'état oligophasé ne représente qu'une forme de passage, et non un état permanent de la matière. On peut donc se demander si l'étendue sur laquelle il peut se présenter n'est pas très réduite, ce qui pourrait réduire l'importance de son rôle géologique ».

Le Prof. GLANGEAUD répond.

Le Prof. SIGNORE résume ensuite les communications suivantes :

GAETANO PONTE : « *Riassunto delle principali osservazioni e ricerche fatte sull'Etna* ».

ALBERT GILLIARD : « *Rapport sur les travaux volcanologiques exécutés en Belgique et au Congo Belge* (1939-1940) ».

MAXIMINO SAN MIGUEL de la CAMARA : « *Volcanoes y erupciones volcanicas de España* ».

GUSTAVE HANTKE : « *Uebersicht über die vulkanische Tätigkeit* 1941-1947 ».

Ont demandé la parole sur ces différentes notes MM. ESCHER, GLANGEAUD, RICHEY, RITTMANN.

4e Séance

(23 août, de 15h à 17h)

Réunion commune avec la Commission pour la structure des Océans et des Continents.

5e Séance

(24 août, de 9h à 13h)

Réunion commune avec l'Association de Séismologie.

Le Dr. STONELEY, Président de l'Association de Séismologie, fait un exposé des mémoires suivants:

Y. KATO: « *Prospecting of the Underground Structure of New Volcano « Showashinzan » by the Seismic Method* ».

T. MINAKAMI: « *Report on Explosive Activities of Andesitic Volcanoes and their Forerunning Phenomena* ».

Le Prof. ESCHER remercie le Dr. STONELEY pour l'intéressante réunion et invite les membres de l'Association de Volcanologie à se réunir dans le bureau de l'Association pour l'élection des membres du Bureau.

L'Assemblée est invitée par le Prof. ESCHER à élire le Président et le Secrétaire général de l'Association.

MM. RICHEY et GLANGEAUD font ressortir la fructueuse collaboration des Proff. ESCHER et SIGNORE et proposent leur élection respectivement comme Président et Secrétaire général. L'Assemblée approuve à l'unanimité.

Le Président Prof. ESCHER souhaite que l' Association puisse continuer à développer les mansions que lui furent assignées à la Réunion de Rome dans le 1922. Il propose que soient nommés Vice-Présidents: le Dr. RICHEY (Grande-Bretagne), le Prof. GLANGEAUD (France), le Dr. ZIES (États-Unis).

Le Dr. RICHEY remercie, mais, puisqu'il a quitté le monde scientifique officiel, il prefère n'être pas réélu. Il propose, si l'Assemblée est d'accord, de nommer le Dr. MACGREGOR.

Le Secrétaire général propose, que, en vue de la compilation du Catalogue des Volcans, le nombre des Vice-Présidents soit élevé à quatre. Il fait relever que le Dr. ZIES, qui pourrait pourtant aider très validement au travail du catalogue, difficilement acceptera, à cause de nombreux travaux qu'il désire terminer avant de laisser son service actif.

Le Dr. RICHEY propose alors le Dr. HOWEL WILLIAMS.

Le Bureau de l'Association internationale de Volcanologie résulte par conséquent constitué de la manière suivante:

Président: B. G. ESCHER (Hollande).

Vice-Présidents: H. WILLIAMS (États-Unis), L. GLANGEAUD (France), A. G. MACGREGOR (Grande-Bretagne), N. NIELSEN (Danemark).

Secrétaire: F. SIGNORE.

Le Prof. SIGNORE informe les présents, que le Prof. ESCHER dans la réunion du soir du 23 août du Conseil de l'Union a soutenu brillament l'activité scientifique de l'Association.

Le Prof. ESCHER refère alors sur le débat du soir précedent; il avait été proposé d'étendre l'activité de l'Association de Volcanologie, en y incluant l'étude de la physique de l'intérieur de la terre. Il avait soutenu que l'Association de Volcanologie demande toutes les ressources d'une association pour continuer effectivement son travail. Cette thèse avait été acceptée.

Le Président Prof. ESCHER présente les travaux suivants en les résumant:

T. MINAKAMI: « *Report on the volcanic activities in Japan during 1937-47* ».

H. TANAKADATE: « *Rapport sur l'activité volcanique du Japon* ».

Le Prof. ESCHER lit aussi les propositions présentées par le Prof. TANAKADATE:

« Subject: *The research and the compilation of the scientific materials concerning the eruption of Syowa-New Mountain of Usu Volcano, Hokkaido, Japan (Since 1943).*

As the activity of the Syowa New Mountain of Usu Vol-

cano, Hokkaido in Japan, since 1943 is one of the most important phenomena not only from the volcanological aspect but from many other geophysical points of view this Association of Volcanology wants earnestly to have the information concerning the whole phenomena of the eruption in detail. Therefore, it will be highly appreciated if the National Research Council of Japan (Ministry of Education) could assist and further the research and complete the compilation of the report.

The Association hopes that the report will be finished and presented to the 9th general assemblage which is expected to be held in 1951 ».

L'Assemblée décide de prier les savants américains de se vouloir intéresser des études sus-dites et de choisir, s'il le croient opportun, des collaborateurs parmi les savants japonais. Parmi ceux-ci ils pourraient choisir le Prof. TANAKADATE pour qu'il puisse continuer ses études sur le volcan Usu.

Le Président propose à l'Assemblée de charger le Vice-Président Prof. HOWEL WILLIAMS de l'Université de California de vouloir s'intéresser de la question. L'Assemblée approuve à l'unanimité.

Le Prof. GLANGEAUD souhaite que les vulcanologues japonais puissent reprendre leurs recherches et apporter de nouvelles contributions à l'étude des volcans. Ils peuvent le faire car ils ont des volcans très intéressants.

Au sujet de la présentation sur le Volcan Usu Mr. L. GLANGEAUD demande si l'intrusion profonde supposée (roof mountain) est sous l'aspect d'un sill local, ou le sommet d'un bysmalite (cylindre) plus ou moins large. Une prospection sismique sur toute la surface du volcan serait intéressante à réaliser. Mr. GLANGEAUD montre des exemples de sills basaltiques (Auvergne, Clermont-Ferrand) et de bysmalite de granodiorite (dacitoide), formations basales de deux types de volcans.

6e Séance

(24 août, de $14^{h}30^{m}$ à $19^{h}30^{m}$)

Réunion commune avec l'Association d'Hydrologie scientifique.

On lit les rapports suivants sur les sources thermales:

« H. SCHOELLER: « *La thermique des eaux souterraines d'origine profonde* ».

S. GUIGUE et G. BÉTIER: « *Les sources thermo-minérales de l'Algérie* ».

F. PAPP: « *Les sources thermales de la Hongrie* ».

T. SZALAI: « *Les sources thermales de Budapest* ».

A. VENDEL: « *Hydrogéologie des eaux sulfatées sodiques-magnésiennes de Budapest* ».

Dans la discussion qui suit parlent MM. ESCHER et GLANGEAUD.

A 16^{h}, le Prof. ESCHER, après avoir remercié le Président de l'Association d'Hydrologie, invite les membres des l'Association de Volcanologie à se réunir de nouveau à 16^{h}30^{m}.

A 16^{h}30^{m} le Prof. SIGNORE fait un exposé des communications suivantes:

L. CUCUZZA SILVESTRI: « *L'eruzione dell'Etna del 1947. Parte I. Fenomeni eruttivi* ».

G. IMBÓ: « *Le recenti manifestazioni eruttive vesuviane* ».

G. IMBÓ: « *Importanza delle determinazioni delle temperature d'irrigidimento delle lave* ».

G. IMBÓ: « *Carattere fondamentale nell'andamento delle variazioni annue nell'inclinazione del suolo all'Osservatorio Vesuviano* ».

F. SIGNORE: « *Il bacino della sorgente delle Caldarelle di Teano* ».

F. SIGNORE: « *L'attività vulcanica nei Campi Flegrei* ».

Le Président ouvre la discussion sur ces mémoires. A la discussion prennent part MM. GLANGEAUD, NIELSEN, RICHEY, RITTMANN, THORARINSSON.

Le Prof. ESCHER résume les travaux de:

VAN BEMMELEN: « *Report on the volcanic activity and volcanological Research in the Indian Archipel during the period 1936-1946* ».

J. J. DOZY: « *Some notes on the Volcanoes of Guatemala* ».

Font des observations MM. NIELSEN et RITTMANN.

Le Prof. GLANGEAUD enfin expose le mémoire de:

JÉREMINE et LUCAS: « *Région volcanique d'Oudja* ».

Le Prof. GLANGEAUD exprime son regret de ne pouvoir participer aux séances successives, car le lendemain il partira pour Londres, où a lieu le Congrès international de Géologie.

7e Séance

(25 août, de 10h à 13h)

Dans la salle de la Présidence se réunissent MM. ESCHER, NIELSEN, RICHEY, RITTMANN, SIGNORE, THORARINSSON pour entreprendre des amples discussions sur la publication projetée du Catalogue des volcans.

Le Dr. J. E. RICHEY présente son

Memorandum on proposed Catalogue of the Volcanoes of the World

The compilation of a Catalogue of the Volcanoes of the World has been an object of the Association for very many years. It was envisaged by the late General Secretary, Professor MALLADRA, and has been advanced by his successor, Professor SIGNORE.

At the Edinburgh Assembly, in 1936, the proposal was considered to be a matter of the first importance, and had the active support of the President, Professor MICHEL-LÉVY.

A format for the Catalogue was drawn up by Professor ESCHER, which was amplified to some extent by the British National Sub-Committee for Vulcanology. The formats were submitted for discussion at the Washington Assembly in 1939, but, in the absence of delegates from Europe at that Assembly, owing to the outbreak of War, decisions had to be postponed. The two formats were published in the Bulletin Volcanologique in 1940.

It is now for the Association to decide upon the measures

to be taken to implement long-standing policy. For purposes of discussion, I am submitting at our Chairman's request certain proposals. These are, in all respects, put forward tentatively, and do not myself speak with an authoritative voice upon the subject. I seek rather to make an initial step in what will be a complex and by no means easy arrangement.

Broad points in regard to the scope, compilation and publication of the Catalogue appear to me to include the following:

Scope of the Catalogue.

1. It is suggested that the Catalogue should be confined to Active Volcanoes, including volcanoes in the solfatara stage. Perhaps the list compiled by KENNEDY and myself and published as a supplement to the 7th volume of the Bulletin (Series 2) may be taken to indicate the majority of the volcanoes to be included.

Professor MICHEL-LÉVY was, I believe, in general agreement with this restriction of the work. At the same time he was anxious that extinct volcanoes which still retained an outward semblance of their form, including such examples as the volcanoes of the Auvergne, should be considered. It is suggested that these extinct volcanoes should form a separate compilation, to be undertaken at some later date. For, if included with the active volcanoes, the task would appear to be too immense or, at any rate, to be beyond achievement within a reasonable length of time. Further, different formats would be required for the two kinds of volcanoes.

2. The formats published in the Bulletin are suggested for discussion and decision. It is regarded as desirable that as comprehensive a format as possible should be available for compilers.

3. It is suggested that the adopted format should be curtailed or otherwise modified by compilers, to suit any particular case they may be dealing with.

Compilation of the Catalogue.

The following suggestions are submitted for consideration.

1. The arrangements for the compilation of the Catalogue should be under the control of the General Secretary.

2. The world should be devided into a series of volcanic regions.

3. A vulcanologist, who, where suitable, would be one of the existing or former officers of the Association, should be selected for putting in charge of one or more regions, as a Regional Compiler, with the following main duties:

a) For assisting the General Secretary in order to obtain suitable individual compilers for different areas, in countries or regions, whether the country concerned is a member of the Union or not. An alternative is to depend upon the National Committees of the countries adhering to the Union, and to confine the activity of the Regional Compiler to non-adhering countries. For the General Secretary to have to deal direct, unless in the initial stage, with National Committee is, I would think, too difficult a procedure. The assent of National Committee shoud howewer, be obtained in regard to a compiler suggested for their country.

b) For assisting the General Secretary in the carrying out of the compilation, in whatever ways the General Secretary should desire, after consultation with the Regional Compiler.

4. Regions are tentatively suggested as follows:

a) Southern Europe and Asia Minor.
b) Africa.
c) India Ocean.
d) New Zealand- Samoa group.
e) New Britain arc.
f) Dutch East Indies generally.
g) Phillipines.
h) Formosa and Japanese arcs.
i) Kurile Islands.
j) Kamchatka and Manchuria.
k) Aleutian Islands and Alaska.

l) Cascade Range.
m) Hawaiian Islands.
n) Central America, including Mexico.
o) South America.
p) West Indies.
q) Iceland and environs.
r) Azores.
s) Atlantic Submarine volcanoes.

5. The compilation should be forwarded to the General Secretary either direct, or through the Regional Compiler, as may be arranged.

6. Funds in aid of compilation which may be required by individual compilers, Regional Compilers or the General Secretary should be supplied by the Association.

Publication of the Catalogue.

It is suggested that:

1. The Catalogue should be published in a series of Parts as separate Volumes. Each part should comprise one or more related regions.

2. Each Part should be put on sale separately, when published.

3. The printing and/or publication of a particular Part may be carried out in a country other than Italy, if circumstances render this desirable.

4. Each Part, as it appears, should be widely advertised for Sale.

5. A limited number only of the Parts of the Catalogue should be distributed to adhering countries. In general, Institutions and Libraries requiring copies should obtain them by purchase.

6. The finances required for printing, publications and advertising should be, in part, a charge on the Association's funds, and, in part, obtained from other sources, either as a loan until reimbursed by sales or as a subsidy.

Initiation of the Catalogue

It is suggested that one particular region or regions, such as would form one part of the Catalogue, should be selected; and that this Part should be compiled, as possible, before arrangements are finally made and initiated for the compilation of other Parts. It is suggested that this initial compilation might be completed before the next General Assembly of the Union, and so would form a basis for further discussion and action by the Association at that Assembly.

Le Prof. SIGNORE présente de la part du Prof. PONTE, Directeur de l'Observatoire de l'Etna, une liste des symboles, que le Prof. PONTE désirerait qu'on adopte dans la composition du Catalogue. Mais après un examen attentif elle n'est pas acceptée, car on croit qu'on ne doit pas augmenter trop le nombre des symboles.

A 13^h la séance est levée et la réunion est renvoyée au jour suivant pour permettre aux présents d'assister à 14^h15^m à la conférence, Associations réunies, du Prof. GUTENBERG, et permettre aussi au Dr. THORARINSSON d'achever les préparatifs pour sa conférence publique.

A 20^h30^m dans l'« Aula » de l'Université, conférence du Dr. THORARINSSON sur:

« *The eruption of Mount Hekla 1947-48* ».

La conférence est accompagnée par projections et par un film, qui reproduit les phases les plus importantes de l'éruption.

À la conférence assistent le Prince héritier de la Norvège, la presque totalité des congressistes et grand nombre de dames et messieurs norvégiens. La conférence a suscité le vif intérêt des convenus.

8e Séance

(26 août, de 10^h à 12^h)

Le Président invite le Dr. RICHEY à exposer les deux communications:

S. I. Tomkeieff : « *The Volcanoes of Kamchatka* ».

A. G. MacGregor : « *Prediction in relation to seismo-volcanic Phenomena in the Caribbean Volcanic Archipelago* ».

A la discussion qui suit prennent part MM. Escher, Nielsen, Wilson, Piggot. Mr. Piggot insiste sur l'importance des recherches de radioactivité.

9e Séance

(26 août, de 14h à 17h)

On reprend la discussion sur le Catalogue des volcans.

On établit d'apporter des changements aux deux esquisses des feuilles reportées aux pp. 77 et suivantes du Vol. VI, Sér. II du Bulletin Volcanologique.

10e Séance

(27 août, de 10h à 13h)

On reprend la discussion suspendue le soir précedent.

On complète l'esquisse des feuilles du Catalogue.

On décide de préparer des exemples sur ces nouvelles feuilles, en choisissant les volcans suivants:

Hekla (Islande)	**qui sera**	**traité**	**par**	**le**	**Dr. Thorarinsson**
Vatna Jökul (Islande)	»	»	»	»	**Prof. Niels Nielsen**
Vésuve (Italie)	»	»	»	»	**Prof. Signore**
Ischia (Italie)	»	»	»	»	**Dr. Rittmann**
Krakatau (Détroit de la Sonde)	»	»	»	»	**Prof. Escher**
Keloet (Java)	»	»	»	»	**Prof. Escher**

Sur ces exemples on établira la forme définitive des feuilles du Catalogue.

On discute enfin sur le choix des collaborateurs. Chaque collaborateur choisira à son tour ceux qui devront l'aider dans la description des différents volcans appartenant à la region qu'on lui a assignée.

Séance plénière de l'Union

(28 août, de 10^h30^m à 12^h30^m)

Le Président de l' Association de Volcanologie, Prof. ESCHER, lit son rapport:

Résumé de l'activité de l'Association Volcanologique Internationale à Oslo

Les séances de l' Association Volcanologique Internationale furent seulement visitées par un nombre limité de vulcanologues. Un vulcanologue étant généralement un géologue spécialisé, la coïncidence du Congrès Géologique International à Londres avec le nôtre devait être fatale à la fréquentation de notre Association.

Une des conséquences directes de cette coïncidence était que toutes les communications devaient être faites par le peu des vulcanologues présents. Or, il me semble qu'une communication perd beaucoup de son importance, quand elle est résumée par une autre personne que l'auteur lui même, une personne, au plus, qui en général ne sera pas capable de répondre aux questions qui se présentent dans la discussion. De fait, dans ce cas une discussion sera impossible et ce ne peut jamais être le but d'un congrès.

Mais heureusement cette situation avait aussi un bon coté. Après que l'un de nos membres nous avait quitté pour joindre le Congrès de Londres, notre nombre était réduit à six, qui formaient une équipe d'une conférence à la table ronde sur un sujet, qui depuis des années figurait dans le programme de notre Association: la composition d'un Catalogue mondial des Volcans actifs.

Il n'existe pas un mode plus court qu'une conférence d'un nombre restreint d'experts pour décider sur la manière et la forme d'un tel catalogue et décider sur faits qui doivent être incorporés, sur la langue dans laquelle il sera rédigé, sur les illustrations qui devront être admises et, problème de toute importance, de choisir les personnes qui seront invitées à col-

laborer. Cette conférence fut faite en français, anglais, danois, italien et « Schwizerdütch ».

En deux journées de bon travail nous pûmes discuter toutes ces questions et maintenant nous avons vraiment commencé ce travail, qui probablement aboutira à un volume d'environ 1500 pages.

Quand ce volume sera prêt, ce ne sera qu'un catalogue préliminaire; car nous sommes bien convaincus des difficultés que nous trouverons sur notre chemin. Il existe des régions volcaniques qui sont mal connues; elles devront être traitées d'une manière moins complète. Mais une fois ce catalogue fini, nous pourrons dire quels vides dans notre connaissance devront être remplis par des expéditions.

À l'instigation du Prof. L. GLANGEAUD un second sujet est mis sur le programme de notre Association. Il s'agit de l'étude des volcans éteints du monde en ce qui concerne la relation entre le temps et le changement de la composition de leurs magmas. C'est le côté pétrogénique de la volcanologie, qui semble être utile à l'avancement de la pétrologie des roches magmatiques.

En terminant, je vous fais savoir que 23 mémoires furent présentés, la plupart traitant de l'activité volcanique, pendant les dix dernières années, de différentes parties du globe ».

B. G. ESCHER
Université de Leiden

Sur l'origine de la forme asymétrique de la surface de la terre et ses conséquences sur le volcanisme de la terre et de la lune.

Discours du Président de l'Association de Volcanologie à la Huitième Assemblée générale à Oslo, le 20 Août 1948. (*)
(Avec 3 figs.)

En étudiant les grands problèmes de la géologie régionale: la distribution des chaînes de montagnes, celle des épicentres de séismes à foyer peu profond ou profond, celle des volcans, on aboutit toujours au problème majeur, celui des continents et des océans. Pour nous, géologues, l'élucidation de ces problèmes ne paraît possible qu'après avoir résolu le plus grand de tous les problèmes géologiques: celui concernant les causes de la distribution des continents et des océans à la surface de la terre.

Par son ampleur, ce problème soulève de grandes difficultés. Partout on s'en occupe, mais personne ne saurait embrasser tous les faits qui doivent être pris en considération pour obtenir la seule solution juste. Chaque géologue part de combinaisons différentes de faits et les solutions sont ainsi nécessairement dissemblables. Il est évident que la solution d'un problème de cette envergure entraine une simplification nécessaire des phénomènes. Aussi les géophysiciens sont obligés de simplifier à un haut degré, pour pouvoir aborder le problème par le calcul.

Mais, en géologie, peu de problèmes supportent un traitement mathématique. La plupart sont trop complexes et contiennent trop d'inconnues. Un choix s'impose alors, en vue d'éliminer différentes inconnues pour pouvoir utiliser ces méthodes. Parfois ce choix est guidé par un jugement subjectif plutôt que par des connaissances géologiques. Le résultat risque d'être gros-

(*) Ce discours fut prononcé en anglais. Le texte anglais a paru dans le « Bulletin of the Geological Society of America », Vol. 60, pp. 353-362, 1949.

sier, ou même sans aucune valeur. Il est vrai que les solutions purement géologiques méritent souvent la même critique. Mais celles-ci s' annoncent, du moins, comme de simples opérations de pensée sans le cadre doré de la mathématique appliquée. Il me semble que l'opinion, qu'une publication géologique avec mathématiques, vaille mieux qu'une autre sans mathématiques, est de nos jours, trop répandue.

Je vous prie de ne pas penser que j'ignore la grande valeur de la géophysique pour la géologie. La science géologique doit beaucoup à la séismologie et à la gravimétrie. Mais dès que la géophysique perd le contact avec la géologie, ce qui veut dire qu'elle ne tient pas suffisamment compte des faits que la géologie a trouvés, elle court le danger de devenir un travail stérile. C'est le géologue et non pas le géophysicien qui devrait donner l'interprétation des observations géophysiques.

La question des continents et océans contient trois problèmes morphologiques :

Premièrement, deux niveaux principaux se présentent à la surface de la terre, le niveau continental à une hauteur moyenne de 875 m. et le niveau océanique à une profondeur moyenne de 4120 m.

Secondement, la proportion des surfaces de ces deux niveaux, que G. K. GILBERT, déjà en 1892, appellait le plateau continental et le plateau océanique, est de 1 à 2 (LITTLEHALES, 1932, donne les chiffres suivants : océans moins les mers continentales 335 millions km^2 ou 66 pour cent, continents plus les mers continentales, 175 millions km^2 ou 34 pour cent).

Troisièmement, il faut remarquer que la distribution des continents est asymétrique. En outre il nous faut considérer ici que les continents se composent de sial, les océans de sima. La doctrine de l'isostasie nous a appris que les continents sont des radeaux de sial, flottant sur le sima.

On connaît diverses tentatives pour expliquer la distribution des continents et des océans avec l'aide de forces qui résident dans la terre. On invoque, le plus souvent, des courants dans le substratum, sous le nom de courants de convection. Avec cette hypothèse, on peut expliquer le premier de nos problèmes morphologiques : l'origine des deux niveaux. VENING-MEINESZ l'a

fait en 1944 (voir aussi 1948), mais sa solution n'est pas d'accord avec les faits qui dominent nos problèmes 2 et 3, car chez lui les deux niveaux ont la même surface et leur distribution est symétrique. La dernière contribution dans ce domaine, celle de G. F. S. HILLS, est capable d'expliquer les problèmes 1 et 2 en reliant la génèse du niveau continental à la naissance du sial. Son idée mérite d'être considérée d'un point de vue pétrogénétique. Mais elle ne tient pas compte du troisième problème.

Supposant la terre fluide et visqueuse, tournant dans l'éspace céleste, elle serait homogène dans le sens tangentiel, tandis que sa densité augmentera dans la direction radiale du dehors au dedans. Selon HILLS le sial provient d'une telle terre primitive par l'action des courants de convection. Des deux hypothèses: « petits courants distribués sur toute la surface de la terre » et « un système organisé de courants », il choisit la seconde. La première aboutirait à « une couverture uniforme de granite sur toute la surface de la terre ». Mais ne voyant aucune possibilité de faire accorder cette supposition avec la distribution actuelle du granite, il part de la seconde hypothèse. Je suis d'accord avec lui, que cette distribution ne saurait être expliquée, la couche de sial une fois formée, par le seul jeu des forces internes. C'est ce que j'ai déjà remarqué en 1945 (p. 5-6 et 20) quand je considérais la conception de H. F. UMBGROVE comme inapplicable. (UMBGROVE, 1942 « A new Hypothesis », p. 104-110). Du reste A. WEGENER (1924, p. 208-209) avait déjà lancé cette idée dans son essence. UMBGROVE a refondu le chapitre en question dans la seconde édition de son livre (1947), mais il retient l'idée que les continents sont formés par un ridement de la couverture sialique originelle de toute la terre.

HILLS donne une explication de la formation de deux continents sialiques aux pôles, qu'il nomme Laurasia et Gondwana, mais il n'explique pas de quelle manière la distribution asymétrique des continents, que nous connaissons, en pourrait être déduite. Même en supposant que ces deux continents polaires seraient déchirés en morceaux de sial, par des courants de convection, dont la chaleur radioactive du sial serait le moteur, nous ne pouvons attendre une configuration aussi irrégulière des radeaux sialiques que nous connaissons.

A. HOLMES (1929 et 1944, p. 505-509) a expliqué la face de la terre de cette manière. Dans ce cas, on devrait supposer que les forces tangentielles exercées par les courants de convection dans le sima, à la base des deux continents sialiques primaires, étaient assez grandes pour les déchirer.

Il me semble que la forme asymétrique de la terre s'oppose à toute explication qui part exclusivement de forces internes.

C'est justement notre troisième problème, l'asymétrie, qui m'a obligé à chercher la solution dans une autre direction, qui a été donnée en principe dès 1882 par OSMOND FISCHER, et que celui-ci a repris dans son « Physics of the Earth's Crust » (1889, p. 336-341). Seule une intervention catastrophale, extérieure à la terre, peut avoir donné la forme asymétrique de celle-ci. Cette catastrophe est le détachement d'une portion de la terre, qui a formé la lune.

Cette explication de l'asymétrie terrestre, entraine deux conséquences.

Premièrement, la terre a dû montrer une differentiation en sial et sima avant la séparation de la lune. Suivant la première alternative de HILLS ce seraient de « petits courants de convection distribués sur toute la surface de la terre », qui auraient donné à la terre une telle enveloppe de sial.

Secondement, nous sommes obligés de supposer que la partie extérieure de cette enveloppe était déjà figée avant le détachement de la lune. Sans cela la terre n'aurait pas gardée la cicatrice du grand évènement.

Si l'on n'accepte pas ces deux conséquences, les autres considérations sont de faible valeur. Je les accepte moi-même, parce que différents phénomènes, non seulement sur la terre, mais aussi sur la lune, trouvent alors une explication logique (ESCHER, 1939, 1940, 1946). Je suppose que la séparation de la lune a eu lieu tout au commencement de l'histoire de la terre, qui a duré selon les nouvelles données de A. HOLMES (1946, 1947), à peu près 3.000 millions d'années, disons dans les premières 100.000 années. A peu près les deux tiers de l'enveloppe sialique de la terre et une partie du sima fut alors entrainée avec une partie de la matière formant le noyau terrestre. Je n'exa-

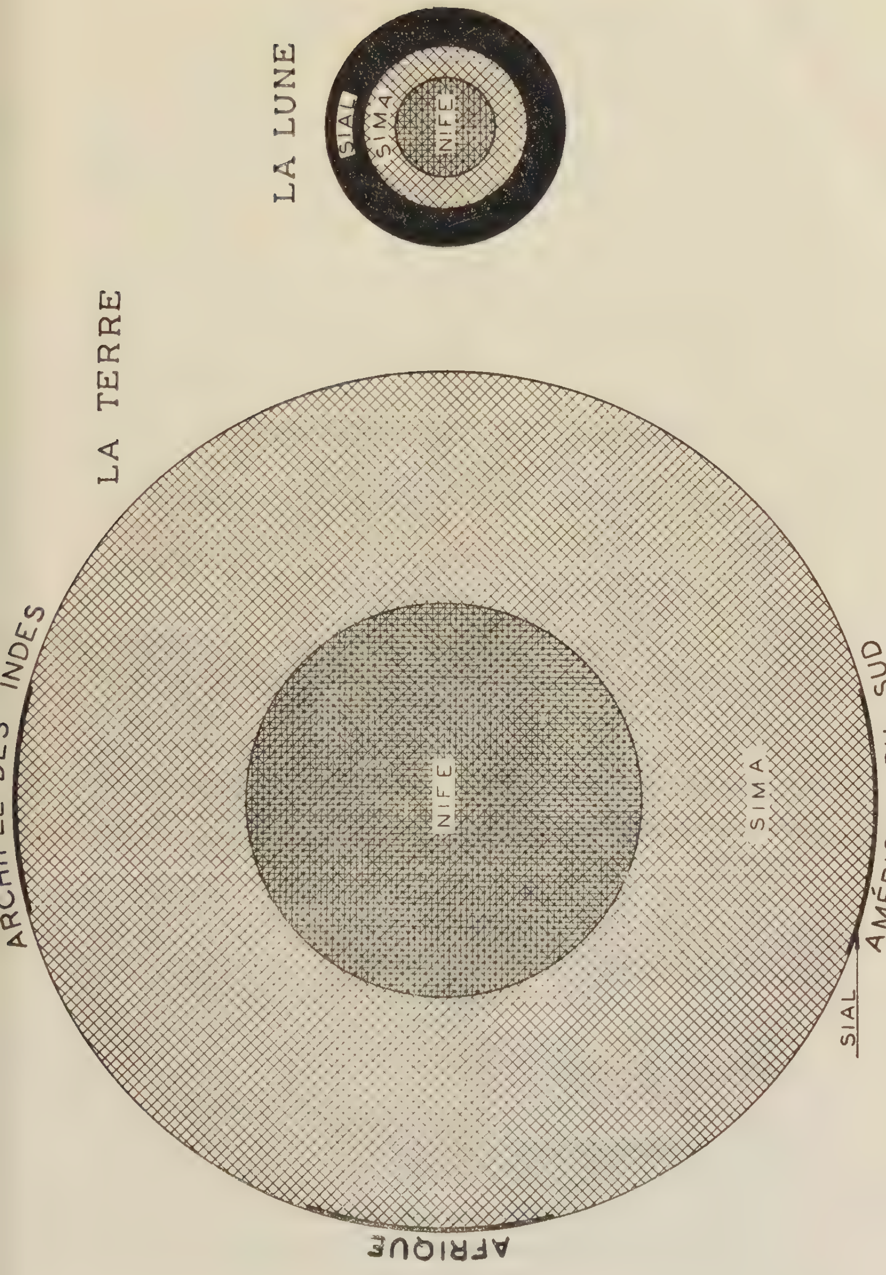

LA LUNE
SIAL
SIMA
NIFE
LA TERRE
ARCHIPEL DES INDES
NIFE
SIMA
AMÉRIQUE DU SUD
SIAL
AFRIQUE

Fig. 1

mine pas de plus près la question de la matière du noyau qui n'a pas une influence sur le problème que nous abordons.

Seule la partie supérieure du sial était cristallisée en ce moment. Mélangée avec une grande quantité de magma fluide, elle dut se fondre dans la sphère qui allait former la lune. On peut se demander si quelques glaçons échappés à cette fonte, n'ont pas formé les « massifs montagneux de la lune », dont l'origine n'a jamais été expliquée.

Un calcul nous montre que si 2/3 de la couverture sialique primitive de la terre a participé à la formation de notre satellite, celui-ci doit avoir une couverture sialique 11 fois plus épaisse que celle constituant les continents terrestres actuels (fig. 1).

S. MOHOROVIČIĆ (1924, 1925, 1927) avait déjà traité ce sujet, mais ne connaissant pas ses publications, je fis quelques calculs simples (ESCHER, 1939, 1940), du reste en partant d'autres prémices.

S. MOHOROVIČIĆ (1927), supposait que la couverture sialique de la terre avait une épaisseur de 20 km. avant la séparation de la lune et qu'elle se serait épaissie à 40 km. en conséquence de la pression tangentielle du sima, qu'il appelle sialma. En outre il supposait que seulement 1/3 de la surface de la couche de sial a été entrainé dans la lune. Par un calcul sommaire, en admettant que la surface de la lune est le 1/15 de celle de la terre, il parvient à une épaisseur du sial lunaire de $\frac{15}{3} \times 20 = 100$ km.

En 1939, je partis de la supposition que le sial des continents n'avait pas été comprimé à l'origine par une pression tangentielle, et que 2/3 de la couverture sialique furent enlevés vers la lune. Comme épaisseur du sial des continents je pris 35 km. La surface de la terre s'élève à 510×10^6 km², celle de la lune à 38×10^6 km²; leur proportion est de 13,4 à 1. En calculant avec la méthode de MOHOROVIČIĆ l'épaisseur de la couche sialique de la lune on obtiendrait $2/3 \times 13{,}4 \times 35$ km. = = 315 km., tandis que j'ai trouvé, d'une manière plus précise, 390 km. Les géophysiciens ne sont pas encore d'accord quant à l'épaisseur du sial des continents. GUTENBERG et RICHTER (1939) admettent 10 à 30 km. de granite.

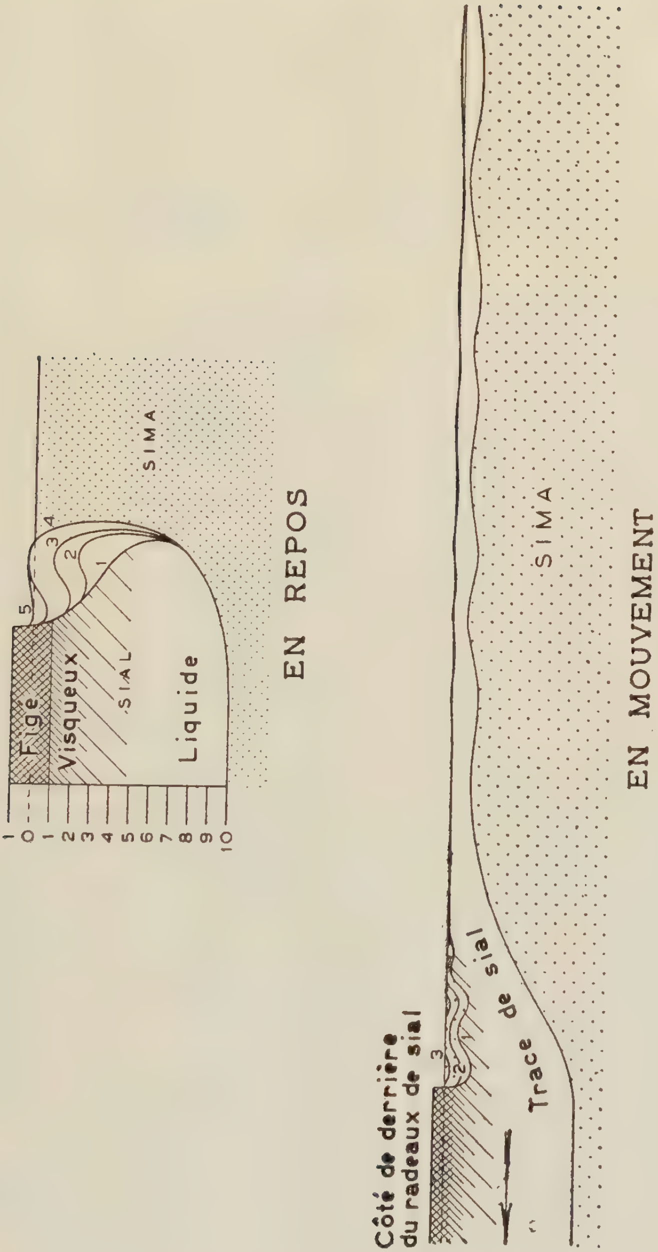

Figé
Visqueux
SIAL
Liquide
SIMA
EN REPOS
Côté de derrière
du radeaux de sial
Trace de sial
SIMA
EN MOUVEMENT

Fig. 2

Pour notre problème, l'épaisseur absolue du sial de la lune est moins importante que l'épaisseur relative, comparée à celle des continents. D'après S. MOHOROVIČIĆ l'épaisseur du sial lunaire s'évaluerait à 2,5 fois celle de la terre, selon moi elle aurait onze fois celle des continents. Dans mon calcul de 1939 je n'ai pas considéré la mince couche de sial des océans atlantique et indien. Cela n'a pas une grande importance pour le calcul. La surface des océans atlantique et indien s'élève à 155 millions de km^2.

Posons l'épaisseur de la couche sialique de leurs fonds à 4 km., le volume s'évalue à 620×10^6 km^3. En remplacement de 11700×10^6km^3 seulement 11000×10^6km^3 de magma granitique auront émigré dans la lune. Cette différence est si petite, qu'elle peut être négligée dans le calcul.

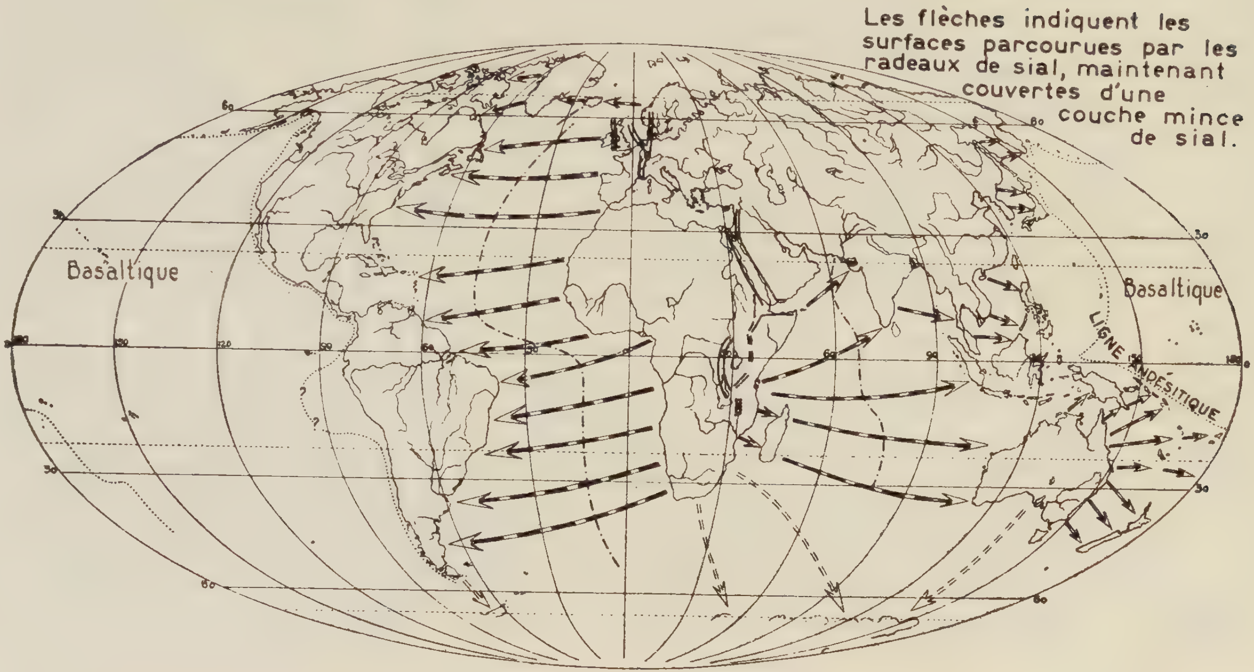
Considérons d'abord les conséquences de cet évènement pour la terre.

Au moment de la séparation de la lune, la dépression qui s'était formée eut tendance à être comblée par le reste de la surface terrestre. L'attraction qui se produisit ainsi découpa en radeaux le reste de la croûte granitique qui flottait vers la plaie. À la base de ces radeaux, le magma granitique, très visqueux, était en voie de cristallisation. Au-dessous, la même substance plus fluide, remontait vers la surface, derrière les radeaux en mouvement (fig. 2), laissant, comme trace du chemin parcouru, une mince couche de sial sur le substratum (fig. 3). Comme les radeaux se précipitaient de tous cotés vers la plaie, ils eurent tendance à former un cercle. Le mouvement fut alors freiné. Les premiers fondements des deux Amériques, de l'Asie, de l'Afrique, de l'Australie et de l'Antarctide furent ainsi arrêtés autour du fond, sur ces entrefaites figé, qui formera beaucoup plus tard, rempli d'eau, l'Océan Pacifique. À ce moment les deux niveaux se manifestent par suite de la moindre densité des radeaux sialiques, comparés au substratum basaltique. Les continents les plus étendus, l'Eurasie et l'Afrique, ayant voyagé moins loin que les deux Amériques, on pouvait prévoir que le sial au-dessous de l'Amérique, est plus mince qu'au-dessous de l' Eurasie et de l'Afrique.

Fig: 3

MOUVEMENT DES RADEAUX DE SIAL VERS LE PACIFIQUE

ET LES GRABEN DE L'EUROPE ET DE L'AFRIQUE



Le fond des océans atlantique et indien comportant une couche mince de sial, il apparaît maintenant trois niveaux sur la terre; le niveau continental à 875 m., le niveau des océans atlantique et indien à — 3950 m. et celui du Pacifique à — 4280 m.

D'après cette hypothèse, les continents auraient subi une seule dérive au début de l'histoire de la terre. En même temps, un réseau de fractures se serait formé dans les continents. F. A. WENING-MEINESZ (1943 et 1948) a interprété ce très vieux réseau de fractures comme résultant d'un déplacement des pôles; et il a ajouté qu'après ce déplacement des pôles, une migration relative des continents était impossible. Je suis persuadé que de telles failles très anciennes existent dans les continents, mais je voudrais les mettre en rapport avec le grand évènement.

L'asymétrie de la terre est illustrée d'une façon particulièrement claire par l'aspect de l'encadrement du Pacifique, bordant le territoire de la dissidence lunaire. Pour ne pas tomber dans trop de détails, je ne veux pas parler de la tectonique et je me bornerai à quelques remarques sur la séismologie et le volcanisme.

En premier lieu, je vous rappelle que d'après GUTENBERG et RICHTER (1945) 80 pour cent des séismes ordinaires (peu profonds) sont circumpacifiques, tandis que seulement 10 pour cent sont situés dans la zône transasiatique de la Tethys.

Tous les tremblements de terre à foyer très profond (> 500 km.) et profond (de 300 à 500 km.) sont circumpacifiques. Seuls quelques foyers intermédiaires (de 90 à 250 km.) tombent en déhors de l'encadrement du Pacifique. C'est bien la preuve que ce territoire et sa ceinture possèdent une position unique à la surface de la terre (voir aussi GUTENBERG, 1939).

Regardons maintenant le volcanisme.

Il est bien curieux que JAMES D. DANA dans son « Characteristics of Volcanoes » (1890) traite prèsque exclusivement le volcanisme des Iles Hawaiiennes. On peut prévoir une contradiction entre le titre et le contenu de ce livre, parce que DANA a étudié un volcanisme qui possède un caractère essentiellement différent de celui de la plupart des volcans terrestres. Il est tout à fait différent par exemple du Vésuve, de l'Etna, du

Krakatau, de Mt. Katmai, du Paricutin, de la Mt. Pelée, du Merapi. Mais soyons satisfaits que le volcanisme hawaiien ait trouvé un si excellent monographe. Dans le Pacifique c'est le sima, qui se trouve à la surface, et c'est justement une particularité de notre planète, tandis que la lune doit posséder une surface tout à fait sialique. C'est pourquoi le volcanisme basaltique, avec ses laves fluides, sa basse pression de gaz et sa faible teneur en gaz, est bien caractéristique de la terre.

Au contraire, les laves provenant du magma sialique, sont beaucoup plus visqueuses, ce qui amène, dans des cas extrêmes, à basse pression de gaz, la formation de cumulo-volcans (Merapi, Mt. Pelée), tandis qu'à l'opposé, les grandes quantités de gaz sous haute pression provoquent la formation de caldéras.

Les éruptions qui se terminent par la formation d'une caldéra, donnent toujours des tufs ponceux, riches en silice (Crater Lake 71% SiO_2, Santorin 65% SiO_2, Krakatau 66% SiO_2, Katmai 77% SiO_2). La formation d'une caldéra est une manifestation typique des magmas acides et, par sa nature, elle n'est pas comparable aux « Volcanic sinks » des volcans hawaiiens.

Le volcanisme terrestre se range entre les deux extrêmes: type hawaiien et type PERRET (ESCHER, 1933 *a*).

Il me semble, que le volcanisme terrestre se lie toujours avec des efforts de traction dans l'écorce terrestre. Cette traction peut être primaire ou bien secondaire. Elle est primaire dans les grands champs de traction (Islande, fossés de l'Afrique orientale) qui sont en même temps des grands champs de fractures. Par contre, elle est secondaire dans les zones de plissement. A. HOLMES (1929) a expliqué comment un effort de traction peut prendre naissance dans une zone de poussée latérale. De mon côté, j'ai essayé de montrer le rapport existant entre cette traction secondaire et le volcanisme (ESCHER, 1933). Pendant que le vrai volcanisme de traction est basaltique, celui des zones de plissement est plutôt intermédiaire ou acide.

La traction primaire prépare la possibilité au sima de s'échapper tandis que la traction secondaire ouvre des foyers de magma sialiques ou bien des foyers, qui, par plissement, sont mixtes, sialiques-simatiques.

La formation d'une caldéra est toujours précédée d'une éruption volcanique très forte; cela signifie une éruption dans laquelle de grandes quantités de gaz s'échappent à haute pression. Or, une pression élevée peut seulement prendre naissance si le toit du foyer magmatique est profond. En 1906 la nuée volcanienne du Vésuve avait une hauteur de 13 km. (F. PERRET, 1924, p. 45), mais en 1883 celle du Krakatau mesurait au moins 50 km. de hauteur (R. D. M. VERNEEK, 1885, p. 123). Donc le toit du foyer magmatique du volcan du Krakatau devait être situé beaucoup plus profond que celui du Vésuve. Selon RITTMANN (1933) le dernier était établi à 5 km. au-dessous de la mer, ou à 6 km. au-dessous du sommet. Le toit du foyer du Krakatau doit forcément avoir eu une profondeur d'un multiple de 5 km. Nous aimerions bien connaître la relation qui existe entre la hauteur de la nuée volcanienne et la profondeur du toit du foyer.

La plupart des vulcanologues sont aujourd'hui d'accord sur l'explication des caldéras par effondrement (p. e. H. WILLIAMS, 1941, C. A. COTTON, 1944, p. 300-316). La forme rigoureusement circulaire des caldéras typiques m'a forcé à abandonner la théorie du simple effondrement du toit du foyer magmatique. A sa place, j'ai donné la théorie de l'effondrement d'un cylindre formé par l'action mécanique du jet de gaz lors d'une éruption type PERRET. Il me semble nécessaire de bien distinguer les vraies caldéras des effondrements tectono-volcaniques (ESCHER, 1927, 1928, 1929). Du reste il semble improbable que jamais un foyer primaire magmatique soit vidé. Je crois que dès que le magma riche en gaz a quitté le foyer, il est remplacé par un magma pauvre en gaz. Par refroidissement de ce magma neuf près des parois du foyer, il se produit une cristallisation et, à la longue, un enrichissement en gaz. Celui-ci provoque un accroissement de la pression qui aboutira par une nouvelle éruption.

Examinons maintenant la morphologie lunaire qui est très différente de celle de la terre. Nous sommes obligés de nous borner aux cirques lunaires (P. PUISEUX, 1908, p. 121-132). Il y a toujours, spécialement en Amérique, des partisans de la théorie qui explique les cirques lunaires par la chute de corps

étrangers. La version moderne de cette conception est celle de R. A. DALY (1946), qui attribue les cirques lunaires à une chute de fragments terrestres, projetés de la terre au moment où la lune fut séparée de la terre. Étant lancés au dehors de la limite de Roche, ils furent attirés par la lune. DALY relève surtout deux arguments contre la formation volcanique des cirques lunaires: leur grande dimension et leur forme régulière auxquelles il ajoute leur abondance relative. Il dit que les caldéras terrestres ont une forme irrégulière. Ici, je ne peux le suivre, parce que les vraies caldéras sont justement très régulières. Il est vrai que les cirques lunaires sont très grands. Leur diamètre est à peu près 10 fois plus grand que celui des caldéras terrestres. Pour cette raison A. WEGENER (1921) ne croyait pas à la formation volcanique des cirques lunaires et les ramenait à la chute de météorites, malgré que le Meteor Crater en Arizona soit dix fois plus petit que les caldéras terrestres, donc cent fois plus petit que les cirques lunaires.

C'est justement une des conséquences de l'hypothèse développée ici, que le volcanisme lunaire a dû être beaucoup plus fort que celui de la terre, parce que la couverture sialique de la lune doit être beaucoup plus épaisse que celle des continents (ESCHER, 1940). Avec cela les deux arguments de DALY sur la grandeur et l'abondance des cirques lunaires sont annulés.

En outre l'explication des cirques lunaires par la chute de corps sur la lune est en contradiction avec le mode d'intersection de ces cirques. C'est une règle rigoureuse sur la lune, qu'un grand cirque est interrompu par un cirque plus petit. L'exemple de Thébit (diam. 49 km.), qui est interrompu par Thébit A (19 km.) qui lui-même est interrompu par Thébit L (10 km.) est très net. (GOODACRE, 1931, p. 169). Il est clair que Thébit s'est formé d'abord, puis Thébit A et enfin Thébit L. A une échelle plus grande on peut nommer Stöfler (160 km.), le plus ancien, Faraday (80 km.), plus jeune et les cirques A et C (30 km.), les cadets. Il est difficile de trouver des exceptions à cette règle. Peut-être Maurolique (120 km.) se serait formé après les cirques plus petits qui le bordent au S. E. Cette observation de petits cirques succédant à des cirques plus grands est tout à fait logi-

que comme conséquence d'un volcanisme décroissant. Nous l'avons faite aussi dans le volcanisme terrestre, p. e. dans le Vulcano Laziale près de Rome avec les cratère-lacs d'Albano et de Nemi. Par contre ce mode d'intersection ne serait pas probable dans la théorie balistique, car il semble invraisemblable que tous les grands projectiles soient arrivés à la lune avant les projectiles intermédiaires et ceux-ci avant les projectiles petits.

Le rapport de F. E. Wright (1935, 1938), sur l'œuvre du « Committee on Study of the Surface Features of the Moon », conclut que la surface de la lune est formée par des « cendres et ponces volcaniques, riches en silice » (1935, p. 113), et il remarque: « Si des roches fermes paraissent près de la surface de la Lune, elles sont maintenant couvertes par des matériaux ponceux » (1938, p. 67). Or, c'est justement les matériaux que nous connaissons dans les caldéras terrestres, et qu'on doit attendre d'éruptions fortes, riches en gaz.

En résumé, les problèmes suivants trouvent une explication logique dans l'hypothèse, développée ici, de la formation de la lune par séparation de la terre:

1. L'asymétrie de la terre.
2. La formation de continents et d'océans.
3. La formation d'une couche mince de sial au fond des océans atlantique et indien.
4. La formation des cirques lunaires.
5. L'activité volcanique plus forte sur la lune que sur la terre.

Aussi, je suis convaincu que pour cette hypothèse les mots de Daly (1946, p. 118) sont valables:

« The correlations demand the pyramiding of assumptions ». Mais je crois être justifié de la présenter parce qu'elle explique de nombreux phénomènes importants.

LITTÉRATURE

COTTON, C. A. — *Volcanoes as landscape forms*. Christchurch, 1944.

DALY, R. A. — *Origin of the Moon and its Topography*. Proc. Amer. Phil. Soc., Vol. 90, pp. 104-119, 1946.

ESCHER, B. G. — *Vesuvius, the Tengger Mountains and the Problems of Calderas*. Leidsche Geol. Mededeelingen, Vol. 2, pp. 51-88, 1927.

——— — *Krakatau in 1883 en in 1928*. Tijdschr. v. h. Kon. Nederlandsch Aardr. Gen., ser. 2, Vol. 45, pp. 715-743, 1928.

——— — *On the Formation of Calderas*. Leidsche Geol. Mededeelingen, Vol. 3, pp. 183-219, 1929.

——— — *On a classification of Central Eruptions according to gas pressure of the magma and viscosity of the lava*. Leidsche Geol. Mededeelingen, T. 6, pp. 45-49 1933 (A).

——— — *On the relation between the volcanic activity in the Netherlands East Indies and the belt of negative gravity anomalies discovered by Vening Meinesz*. Kon. Akad. v. Wetenschappen, Proceedings, Vol. 36, pp. 677-685, Amsterdam, 1933 (B).

——— — *Rapport sur les phénomènes vulcanologiques dans l'Archipel Indien pendant les années 1933, 1934 et 1935 et sur les ouvrages de volcanologie publiés durant ces années, concernant les volcans des Indes Neérlandaises*. Bull. volcanologique. Organe de l'Association de Volcanologie, Sér. II, T. I. pp. 127-177, Napoli, 1937.

——— — *Moon and Earth*. Kon. Akad. v. Wetenschappen, Proceedings, Vol. 42, pp. 127-138, Amsterdam, 1939.

——— — *Het probleem der Maancircussen*. Hemel en Dampkring, 38e Jaarg., pp. 185-194, 1940 (a).

——— — *Het probleem der caldeira's en der maancircussen*. Geologie en Mijnbouw, pp. 133-143, 1940 (b).

——— — *De asymmetrische gedaante der aarde en haar oorzaak*. Rede, Leiden, 8 Fbr. 1946.

FISHER, OSMOND. — *On the physical cause of the Ocean Basins*. « Nature », vol. XXV, pp. 243-244, 1882.

——— — *Physics of the Earth's Crust*. Macmillan and Co., London and New York, 1889.

GILBERT, G. K. — *Continental Problems of Geology*. Smithonian Report to July, 1892, pp. 163-173, Washington, 1893.

GOODACRE, W. — *The Moon*. Bournemouth, 1931.

GUTENBERG, B. — *The structure of the Pacific Basin as indicated by Earthquakes*. Science, Vol. 90, pp. 456-458, 1939.

GUTENBERG, B. and C. F. RICHTER. — *Structure of the Crust. Continents and Oceans*, in : Internal Constitution of the Earth. (Physics of the Earth VII), pp. 301-327), New York, 1939.

——— — *Seismicity of the Earth. Supplementary Paper*. Bull. Geol. Soc. America, Vol. 56, pp. 603-668, 1945.

HILLS, G. F. S. — *The Formation of the Continents by Convection*. Edward Arnold & Co, London, 1947.

HOLMES, A. — *Radioactivity and Earth Movements*. Transactions Geol. Soc. of Glasgow, Vol. XVIII, Part III, pp. 559-606, 1929.

——— — *Principles of Physical Geology*. Thomas Nelson & Sons Ltd., London, 1945.

——— — *An Estimate of the Age of the Earth*. Nature, Vol. 157, p. 680, 1946.

——— — *A Revised Estimate of the Age of the Earth*. Nature, Vol. 159, pp. 127, 1947.

JEFFREYS, H. — *The Earth*. Sec. Edit., Cambridge, 1929.

LITTLEHALES, G. W. — *The configuration of the Oceanic Basins*. In: Physics of the Earth V, Oceanography, pp. 13-46, Bull. Nat. Research Council, nr. 85, Washington, 1932.

MOHOROVIČIĆ, S. — *Ueber die Konstitution des Erd- und Mondinnern*. Astronomische Nachrichten, Bd. 220, Nr. 5271, Kolom 245-250, Kiel, 1924.

——— — *Das Erdinnere*. Zeitschr. f. angewandte Geophysik, Bd. I, S. 330-383, Berlin, 1925.

——— — *Ueber Nahbeben und über die Konstitution des Erd- und Mondinnern*. Gerl. Beiträge zur Geophysik, Bd. 17, pp. 180-231, 1927.

PERRET, F. A. — *The Vesuvius Eruption of 1906*. Carnegie Institution of Washington, Publication No. 339, 1924.

PUISEUX, P. — *La Terre et la Lune*. Paris, 1908.

RITTMANN, A. — *Die geologisch bedingte Evolution und Differentiation des Somma-Vesuvmagmas*. Zeitsch. f. Vulkanologie, Bd. 15, pp. 8-94, 1933.

UMBGROVE, J. H. F. — *The Pulse of the Earth*. M. Nijhoff, The Hague, 1942, Sec. edit., 1947.

VENING MEINESZ, F. A. — *Spanningen in der aardkorst tengevolge van poolverschuivingen*. Verslagen Ned. Akad. v. Wetenschappen. Afd. Natuurkunde, Vol. LII, pp. 185-196, Amsterdam, 1943.

——— — *De verdeeling van continenten en oceanen over het aardopperolak*. Verslagen Ned. Akad. v. Wetenschappen, Afd. Natuurkunde, Vol. LIII, pp. 151-159, Amsterdam, 1944.

Vening Meinesz, F. A. — *Shear patterns of the earth's crust*. Trans. American Geophys. Union., Vol. 28, pp. 1-61, 1947.

——— — *Major Tectonic Phenomena and the Hypothesis cf Convection Currents in the Earth*. Quarterly Journal Geol. Soc. of London, Vol. CIII, pp. 191-207, 1948.

Verbeek, R. D. M. — *Krakatau*. Batavia, 1885.

Wegener, A. — *Die Entstehung der Mondkrater*. Sammlung Vieweg, Heft 55, Braunschweig, 1921.

——— — *Die Entstehung der Kontinente und Ozeane*. 4e Auflage, Vieweg & Sohn, Akt. Ges., Braunschweig, 1929.

Williams, H. — *Calderas and their origin*. Univ. Cal. Publ. Bull. Dept. Geol. Sci. 25 (6), pp. 239-346, 1941.

Wright, F. E. — *The surface Features of the Moon*. The Scientific Monthly, Vol. XL, pp. 101-115, 1935.

——— — *The Surface of the Moon*. Carnegie Institution of Washington, Publication Nr. 501, pp. 59-74, 1938.

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REPORT

CONSEIL INTERNATIONAL DES UNIONS SCIENTIFIQUES
INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS (I.C.S.U.)
COMMITTEE ON SCIENCE AND ITS SOCIAL RELATIONS (C.S.S.R.)

A) « *What are the present possibilities for prediction of the behaviour of volcanoes and*
B) « *for mitigating the devastating effects of eruptions?*
C) « *What investigations are going on concerning this subject, and*
D) « *how is cooperation organized between tho bodies occupying themselves with such work?* »

A) « *What are the present possibilities for prediction of the behaviour of volcanoes?* »

Considering that each volcano has its own character, it is only possible to predict its behaviour after a long and exhaustive study of the way it has behaved in the past. The greater the compilation of statistical data about a volcano, the greater the chance that predictions about its behaviour will come true. So, for each suspect volcano we not only need a history of its eruptions as exhaustive as possible, but also a continual guard. Naturally only those volcanoes that threaten important centres of population, are regularly watched. What a volcano must especially be watched for, only appears when its character has become more or less known

Generally the local volcanic vibrations must be registered with the aid of a seismograph. In some cases it is desirable to observe regularly the temperatures of fumaroles, in others to measure the slow motion of the bottom (« tilting »). Further, gravity measurements are recommended by the side of magnetic ones.

Although it is a known fact that a volcanic eruption is generally preceded by local earthquakes and by a rise in the temperature of fumaroles, it is, in the case of most volcanoes, not known what form of temperature-rise and what sort of vibrations

point to an approaching eruption; neither do we know what period of time lies between these warnings and the eruption. Only very few volcanoes are watched regularly and that only since a few years. (Vesuvius, Etna, Mt. Pelée, Kilauea, Mauna Loa, some Japanese volcanoes (1) and in the Dutch East Indies: Tangkoebanprahoe, Papandajan, Tjerimai, Merapi, Keloed, Lamongan, Kawah Idjen, all situated on Java, and Awoe Poelau Sangihe (Sangir Islands).

The chance of predicting a future eruption is, even for most of the volcanoes mentioned above, extremely small, because some volcanic cycli must have elapsed before the character of a volcano can be sufficiently known. Although something is roughly known about the characteristics of volcanoes, this is not nearly sufficient to enable us to predict the future behaviour of a volcano from a short period of observation. Also, many more volcanoes than up to now must be taken under regular observation.

The character of the volcanoes on Hawai of which records have been made for about 70 years, is better known than that of any other volcano, and T. A. JAGGAR has as a matter of fact succeeded in predicting an eruption of Mauna Loa. On March 27, 1934 he foretold an outflow of lava from this volcano towards Hilo, to take place whithin two years and on November 21, 1935 the first rapid flows of an upper vent began at a height of 12.000 feet, followed on the 22nd of December 1935 by flows of lava from a lower vent at a height of 9.000 feet towards Hilo. It is no depreciation of T. A. JAGGAR's splendid work when we point out that the behaviour of many other volcanoes is more difficult to predict because their characters are more unstable. It is much more difficult to make a prognosis entailing the element of time for Vesuvius, notwithstanding this volcano is known much longer.

It is known that Keloed, on Java, has since 1811 an average of one eruption in 18 years, with intervals of 15, 9, 13, 16, 37 and 18 years. (ESCHER 1919). The last eruption occurred in 1919, and so now, after 1937, an eruption may be expected at any moment. But it is only after the eruption of 1919 that the

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(1) The correspondent has, as yet, received no answer from Japan.

temperature of its fumaroles are regularly observed and that a seismograph registers the vibrations of the soil. By this means it is hoped that it will be possible to warn the population in time.

B) « *What are the present possibilities for mitigating the devastating effects of eruptions?* »

1. In the first place a preventive service must be established for each volcano menacing a population. For this it is necessary that the volcano is continually watched and that the post of observation is connected by wire with the areas menaced. The observatories on Vesuvius, on Etna and on the edge of Kilauea (Volcano House), above St. Pierre on Martinique (Mt. Pelée), on Merapi, Keloed, and many others fulfill this task. Merapi, in central Java, which, in connection with the descent of avalanches of incandescent sand with glowing clouds, shows an extremely dangerous character, is watched by two posts of observation: Badadan and Krindjing. In case of bad sight Badadan is warned when a glowing cloud descends the Senowo Ravine by apparatuses that give the alarm as soon as the temperature in the Senowo Ravine rises above 50°C.

2. Further, as many as possible *special precautions* must be taken adapted to the character of the volcano. Just as in areas subject to earthquakes new houses must be built according to special directions, it might e. g. be recommended to build, in every village around Vesuvius a shelter with a strong, sloping roof, so that what happened in 1906 cannot be repeated. During the night of April 7 the population of San Giuseppe fled into the church and the flat roof which could not bear the weight of ashes and lapilli, collapsed and crushed 105 people (Perret 1906, p. 62). Keloed on Java derives its dangerous character from the sudden ejection of the water from the crater-lake. In 1919 40 million m^3 of water were ejected, causing a flow of mud in consequence of which 5500 people perished. The « Dienst van de Mijnbouw in Nederlandsch Indië » has since then drained the greater part of the lake water through tunnels, so that about 2 million m^3 water remains, which it is difficult to remove in connection with the continual changes in the bottom of the crater. (Tromp 1926). It

is hoped that the result of this will be that a following eruption will have less serious results. The costs of this work amounted to 1,300,000 guilders.

Not only has T. A. JAGGAR given a timely warning of the eruption of Mauna Loa, but he has also pointed out the means to save Hilo from a lava-stream. They have been executed and proved to be effective (JAGGAR 1936). It must not be expected, however, that the same means can be successfully applied to every lava flow, because their characters may differ widely. JAGGAR knew that the lava of Mauna Loa is rich in gases and therefore a thin fluid, he knew that these flows (« the tunnel-flowing variety called pahoehoe ») at once form a crust by freezing and continue their way enclosed by a tunnel, without losing gas. He reasoned that, if those tunnels were destroyed, the gas would escape, the lava become less fluid, flow more slowly, solidify sooner, stop less far from its source, and might, by local solidification, be forced to follow another direction. On December 27, 1935 the 23rd and 72nd Bombardment Squadrons dropped twenty 600 pound bombs from bombing-planes on to places of the lava tunnel indicated by JAGGAR and with complete success. Five direct hits stopped the lava stream. Whereas on December 27 at 12.00 noon the speed of the frontal motion amounted to 800 feet per hour, it was at 4.00 p. m. 150 feet per hour, on December 28 at 10.30 a. m. 44 feet per hour, and at 6.00 p. m. O feet per hour. A. RITTMANN (1938) reports to have proposed a similar measure for Vesuvius to the Military Service in 1929, which was, however, not accepted. Prof. G. PONTE from Catania informed me that it is intended, if necessary, to lead the next lava stream from Etna, into another direction by bombing.

In order to protect Hilo, which is threatened by future lava-streams, JAGGAR proposed to build three embankments oblique to the course of expected lava flows, that must prevent a future « aa » lava stream, which flows much more rapidly than a pahoehoe stream, from reaching Hilo. Bombing of an « aa » stream, JAGGAR considers useless. The costs of construction of these three embankments are estimated at $ 800,000.

In the Commonwealth of the Philippines the volcanoes *Mayon* and *Taal* are the most dangerous. After the eruption of

Taal in February 1911, which cost the lives of 1400 people, it was forbidden to settle on the island in Lake Taal. Timely measures have resulted in nobody losing their lives in the eruption of Mayon in 1928 and 1938.

Lastly we must state here that, after the eruption of the volcanoes « Vulcan » and « Matapi » in Blanche Bay (New Britain, Australian Mandated Territory of New Guinea) during which Rabaul was partly destroyed, a report was issued by Dr. W. G. WOOLNOUGH, Commonwealth Geologist, and Dr STEHN, Chief of the Netherlands Indies Volcanological Survey.

Temporary measures have been taken to protect the population around Blanch Bay, (which is living in an active caldera !) from a probable new eruption. The Government has decided to abandon Rabaul as capital of the Territory and to found a new capital, which will probably be situated on New Guinea. In this case the way to protect people, goods and chattels consists of a flight to less dangerous regions.

C) « *What investigations are going on concerning this subject ?*

By the side of the Volcanological Surveys and Observatories already mentioned, and which not only continually watch and regularly survey certain volcanoes but also visit and examine other volcanoes in connection with a warning or an eruption, incidental examinations take place as well.

Thus the island *Montserrat* (Leeward Islands) was examined by C. F. POWELL and A. G. MAC GREGOR in 1936 (MAC GREGOR 1938) in connection with the increasing frequency of seismic shocks and the abnormal gas emission from the souffrières in 1934 and 1935. Alarming phenomena were not discovered.

The Government of the Commonwealth of the Philippines has under serious consideration the establishment of a Volcanological Division for the study of the Philippine Volcanoes and the protection of life and property in time of eruptions.

D) « *How is cooperation organized between the bodies occupying themselves with such work ?* »

A close cooperation does, as yet, not exist. A loose connection is however formed through the « Association of Volcano-

logy of the International Union of Geodesy and Geophysics ». The secretaryship of the « Bureau Central de Volcanologie de l'Union géodésique et géophysique internationale » is established at Naples. The address of the secretary is: Prof. Francesco Signore. Via Tasso 199. Napoli. Italy.

Leiden, May 1939.

BIBLIOGRAPHY

(1) B. G. ESCHER. *De Kloet.* Waterstaats-Ingenieur. Weltevreden 1919, pp. 304-309.

(2) A. G. MAC GREGOR. — *The Royal Society expedition to Montserrat, B. W. I. The Volcanic History and Petrology of Montserrat, with observations on Mt. Pélée, in Martinique,* Phil. Trans. Royal Soc. of London. Series B. Biological Science. No . 557, Vol. 229, pp. 1-90. March 29, 1938.

(3) TH. A. JAGGAR. — *The coming Lava Flow.* The Honolulu Advertiser, March 27, 1934.

(4) ——— — *The Bombing of Mauna Loa,* 1935. The Military Engineer, July-August, 1936.

(5) ——— — *Protection of Hilo from coming Lava-flows.* Delivered at Annual Meeting of Chamber of Commerce of Hilo, Hawaii, Jan. 19, 1937.

(6) F. PERRET. — *The Vesuvius Eruptions of 1906, Study of a Volcanic Cycle.* Carnegie Institution of Washington. Publ. n. 339, 1924.

(7) A. RITTMANN. — *Vulkanismus.* In: Geologische Jahresberichte, Band 1, 1938.

(8) H. VAN HETTINGA - TROMP. — *De aftapping van het Kloetmeer.* De Ingenieur. Dl. 41, Febr. 13, 1926, 109-118.

J. J. DOZY

Some notes on the Volcanoes of Guatemala

(With 5 text-figures and 11 plates)

CONTENTS

I. — Introduction

The excellent aerial photographs of some Guatemalan volcanoes taken by Fairchild Aerial Survey's Inc. in 1938 form the excuse for the present paper. The author has perhaps not many new facts to offer, nor has he given an up-to-date review of our knowledge of the Guatemalan volcanoes, but in describing and explaining the photographs he wished to take this opportunity of drawing attention to some of the many interesting problems in this Central American Republic which are still outstanding. The fair accessibility and the many, though scattered, outcrops of sedimentary and basement rocks beneath the sometimes rather superficial cover of volcanic deposits, make it possible to study in Guatemala not only the young volcanoes and their attendant phenomena, but also the relationship of geological structure with the various phases of post-Cretaceous volcanicity.

Before continuing the writer would like to express his feelings of respect and gratitude to the Sociedad de Geografía e Historia de Guatemala, whose library he was allowed to consult during his stay in Guatemala. Unfortunately he was unable to check thoroughly, whilst compiling this article, whether more recent literature existed on the subject. Finally he wishes to acknowledge his indebtedness to « De Bataafsche Petroleum Maatschappij » at The Hague and « Fairchild Aerial Survey's Inc. » at Los Angeles (Cal.) for their permission to publish this paper and the aerial photographs.

II. — **Present-day volcanoes**

The volcanoes of Guatemala form the beginning of a zone of volcanic activity extending in a general southeast direction throughout Central America and roughly parallel to the present coast line of the Pacific Ocean. Practically speaking this zone begins at Mexican-Guatemalan border with the 4064 m high Tacaná volcano, only one small volcano, Boquerón, (WAIBEL) occurring about 25 km further to the NW in Mexico. Within Guatemala this zone of volcanoes broadens towards the southeast.

An alignment in longitudinal rows, as indicated by several authors, is not very apparent in detail. One rather gains the impression that the occurrence of the volcanoes is, at least in the west, restricted to a fairly narrow zone. Very pronounced, however, is a transverse arrangement, as if vents were located on faults or fissures more or less at right angles to the direction of the main zone of volcanism. DOLLFUS and DE MONTSERRAT recognized this fact already. The most conspicuous transverse rows are:

Cerro Quemado - Santa María - Santiaguito
Cerro de Oro - Tolimán - Atitlán
Acatenango - Fuego.

The following is a list of the more important volcanoes taken in part from REYES. VON WOLFF gives short additional information on most of them. For their location we refer to the map fig. 1.

Fig. 1. — Map of southern Guatemala.

Name of volcano	Ref. number KENNEDY & RICHEY	Altitude (metres)	Remarks; Years in which activity reported
Tacaná	342	4064	1855
Tajumulco	343	4210	
San Antonio		2250	
Lacandón		2748	
Siete Orejas		3361	
Chicaval		2830	
Cerro Quemado	344	3179	1785, 1891
Santa María	345	3768	1902, 1922, 1929 (Santiaguito)
Zuñil		3533 (3553 v. W)	
Santo Tomás		3505 (3551 v W)	
San Pedro		3024	
Santa Clara		2847	
Cerro de Oro		1894	
Tolimán		3153	
Atitlán	346	3525	1469 (acc. to Indian tradition) 1717-1721, 1826 (v. W), 1827-1828, 1833, 1843 (v. W), 1852, 1856.
Acatenango	347	3960	1924-1926
Fuego	348	3835	1524 (v.W), 1526 (D&M) 1541 (D & M), 1576 (v. W), 1581-1582, 1585, 1614, 1623, 1686, 1699, 1705-1707, 1710, 1717, 1732, 1739, 1799, 1829, 1855, 1856, 1857, 1860 (v. W), 1880, 1932.
Agua		3752	

Name of volcano	Ref. number KENNEDY & RICHEY	Altitude (metres)	Remarks: Years in wich activity reported
Pacaya	349	2544	1565, 1651, 1664, 1668, 1671, 1674 (v. W), 1677 (D & M), 1690 (v. W), 1775, 1846 (v. W).
Cerro Redondo		1267	neighbourhood of Barbarena
Sumasate		1322	
Cerro Alto		1600	
Cerro Gavia		abt 1500	volc. origin doubtful (v. W)
Cerro Raxon		abt 1500	volc. origin doubtful (v. W)
Jumaitepeque (Jumay)		1810 (1598 v. W)	
Tecuamburro		1946	
Tobón		1800	
Jumay (Jalapa)		2200 (2160 v. W)	
Alzatate		2750	
Amayo (Flores)		1050 (1810 v. W)	
Moyuta		1684	
Tahual (Tahualca)		1500 (1700 v. W)	
Culma		1060	
Suchitán		2042	1469 acc. to Indian tradition
Ipala		1670	
Monterico		1320	
Iztepeque		1300 (1320 v. W)	known for the occurrence of Obsidian
Chingo		1780 (1783 v. W)	
Ticanlù		773	
Quetzaltepeque		1200	

Alternative figures for elevations and years of eruption have been indicated with the initials of the authors mentioning them: v. W, VON WOLFF; D & M, DOLLFUS and DE MONTSERRAT.

III. — Structure of the pre-volcanic basement

When we try to visualize the Guatemalan volcanoes in their wider setting we are struck by the fact that the higher and more recent cones are arranged in a fairly narrow zone, which is not only parallel to the coast line of the Pacific Ocean, but, more significantly, also to a deep sea trough about 500 km long and running in front of this section of the Pacific coast. It seems therefore logical to assume that at least the present Guatemalan volcanoes are a circum-Pacific phenomenon.

To a person unacquainted with Central American geology this might not seem an observation of great importance. If we try, however, to reconstruct the lay of the land before the widespread volcanics were deposited and we look at the structure of the pre-volcanic basement, the existence of a different trend strikes our attention. For this reason we will give a brief summary of our present knowledge of the geological structure of central Guatemala.

Apart from the northern foreland of El Petén and Yucatán at least three main tectonical units can be recognized. These are from N to S (see also map fig. 1):

1. The Altos Cuchumatanes and the Mountains of the Alta Verapáz consist of strongly folded Palaeozoic shales with intercalations of dolomites and limestones of a Permian age (Fusulina). This Palaeozoic series is covered unconformably by Mesozoic red or varicoloured sandstones and shales with some limestones and gypsum horizons of the Todos Santos Series. A gradual transition seems to take place upwards into a thick sequence of predominantly limestones and dolomites of Middle (Orbitolina) and Upper Cretaceous (Rudists) age.

This first tectonical unit is bordered to the South by a strongly disturbed zone probably passing through Cuilco which we could further follow from San Sebastián (WNW of Huehuetenango), Chiantla, Aguacatán, Sacapulas, along the valley of the Rio Negro eastward to Santana, Santa Rosa and along the depression of the Rio Polochíc towards Lago de Izabál. In this strongly disturbed zone lenticular masses of Serpentine occur which could be Cretaceous in age or older.

2. A second tectonic unit constitutes the Sierra de Chuacús - Sierra de las Minas and the Montañas del Mico. It consists chiefly of crystalline schists and eruptive rocks such as serpentines, granitic intrusives, gabbroid dikes, etc. It is covered at its eastern end in the Sierra de San Gil (WSW of Pto Barrios) by crinoidal limestones of a Permian age. This second unit is apparently upthrusted towards the north against the Palaeozoic and Cretaceous sediments of the first unit.

Towards the south occurs a very marked morphological depression, followed by the waters of the Rio Grande and the Rio Motagua. We believe that this depression represents again a zone of major disturbance, separating two important tectonical units. We observed strongly pressed sediments; lenticular masses of limestone (Gualán) and relatively young folded sandstones and conglomerates overlying tuffs and possibly of a Tertiary age.

3. The southernmost unit consists of mica schists with extensive granite intrusions accompanied by acid and more basic dikes. Zones of intercalated Mesozoic sediments indicate a more complex tectonical structure. This third unit is covered to a very large extent by younger volcanic deposits with the basement rocks exposed mostly in local inlayers. The latter are granites and limestones with Orbitolina or Rudists (e. g. N of Guatemala, Lago Atitlán etc.) or limestones and conglomerates (surroundings of Lago de Ayárza).

From the above it is clear that Guatemala belongs to the east-west trending Central American - Antillean geoanticline which in the area mentioned bends slightly to the ENE. The tectonical movements seem to have been directed towards the north and the main diastrophism is probably of a late Cretaceous age, since tectonic units 1 and 3 both contain Cretaceous limestones of the same facies. The Pacific trend of the recent volcanoes developed diagonally across the E-W Central American trend. It is from present data not clear exactly when and how this new trend originated. In any case the Rio Motagua syncline seems to have been affected again by late Tertiary movements and we believe that extensive extrusive activity had already taken place before that time.

IV. — **Tertiary volcanic deposits**

The strongly folded rocks of the third, and to a certain extent also those of the second tectonical units, are unconformably covered by volcanic deposits (see map fig. 1), which SAPPER took together on his geological map as « young eruptive rocks ». We believe that at least two groups of volcanic rocks might be recognized. It struck us that deposits, presumably of an older volcanic phase, are generally rather strongly pressed and folded. Tuffs show diagenetical hardening, occasionally thin bedded possibly lacustrine intercalations occur and locally tuffs are laminated giving the impression of sub-aqueous sedimentation. Such lacustrine deposits are sometimes steeply folded. This is the case between San José Pinula and Mataquescuintla, also at some localities in the mountains between Tecpán and Totonicapán. In general the mountains composed of these older volcanic rocks no longer show a typical volcanic morphology. We therefore are tentatively inclined to ascribe to these rocks a Tertiary age. SAPPER reckons already with a possibly Tertiary age of the volcanic activity and we may recall in this connection the andesitic components occurring in folded conglomerates, sands and marls in the Rio Motagua valley, which he, admittedly tentatively, ascribed to a Mio- or Pliocene age. Also WAIBEL assumed that the Tacaná volcano commenced its activity in the Tertiary. In this connection we might mention the three volcanic phases recognized by SONDER and BURRI in Nicaragua, viz. 1. Lower Tertiary, 2. Mio-Pliocene, 3. Quaternary (SAPPER).

In any case it seems that in Guatemala folding and faulting took place after the deposition of a large amount of volcanic rocks and sediments, such as, for instance, those we find nowadays outcropping in the mountains between Totonicapán and Tecpán, in the Montaña de las Nubes and perhaps between Guatemala and Antigua. This older volcanic series is apparently rather widespread to the immediate north of the zone of more recent volcanoes.

V. — Quaternary volcanic deposits

If we identify tentatively the tectonic movements affecting the older volcanic deposits with the Pliocene diastrophism of SAPPER and SCHUCHERT, then the more recent volcanic deposits must be Quaternary in age. Frequently some indications of origin can still be recognized in their morphology. Many volcanic cones or volcanic ruins can readily be recognized as such in the field; huge tuff plateaux, sometimes intensely cut up by erosion, are still apparent.

The age of the bulk of these younger volcanic deposits is most likely Pleistocene. We found during 1939 a lower jaw of Megatherum in a bone breccia about 1 metre below the surface interbedded with horizontal tuff agglomerates on the finca «El Cairo» near the village of Lagunillas on the plain some 9 km to the SE of the volcano Pacaya, thus confirming again a Pleistocene age for these deposits, although it is, of course, not excluded that these younger volcanic deposits range all the way from a Pliocene age up to recent time.

The present volcanism is, it seems, only the extension or continuation of the Pleistocene activity.

In historical times lava in some fair quantity has only been produced twice: on Cerro Quemado in 1785 and on Pacaya in 1775. The youngest activity of Santiaguito (Santa María) in 1929 produced a plug and a very small quantity of lava, whilst Fuego produced some in 1857. All other eruptions seem to have been of an explosive nature. From a geological point of view there are perhaps two significant eruptions in historical time in this general area, viz. Coseguina (in El Salvador) in 1835 and Santa María in 1902. An estimated 50 and 5½ cubic kilometres respectively of loose material were ejected. We are therefore inclined to believe that the present phase is essentially explosive.

VI. — Description of some recent volcanoes and volcanic phenomena

We now come to the description of a few recent volcanoes, to which we add some remarks on the origin of a few well

known lakes supposedly of volcanic origin. Santa María, the most famous of Guatemalan volcanoes, has not been mentioned however. The tremendous explosive eruption of 1902 and the less important one of 1929 directed wide interest to this mountain and we therefore refer to the papers by K. SAPPER, F. TERMER, T. ANDERSON, a. o.

a) **Atitlán and Tolimán**

Photograph 1 shows in the foreground from left to right the volcanoes Atitlán and Tolimán viewed from the east. They form, together with the next row, Santa Clara and San Pedro, the background of the picturesque Lago de Atitlán, part of which is still visible on the right of the photograph. Both rows are orientated in an approximately N-S direction. Atitlán (also

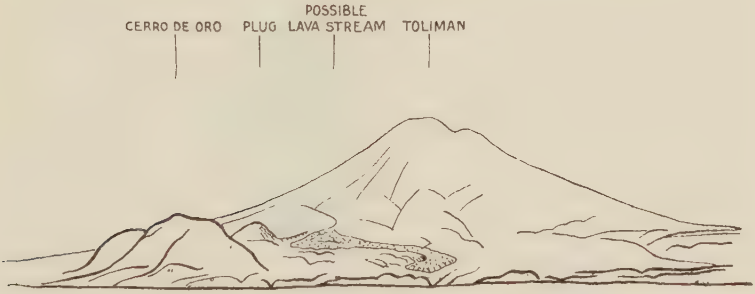

Fig.. 2. — North flank of Tolimán, seen from lake Atitlán.

called Suchitepequez) seems to envelop Tolimán (Casuela Juyu or San Lucas), which is the older of the two. ANDERSON climbed it and described a small crater on its summit. Tolimán has two separate summits situated on a N-S line. A few phenomena, on the north flank of Tolimán show the same direction (see fig. 2), namely a small cone called Cerro de Oro near the lake shore and somewhat higher up the N flank a plug, whilst it seems, as observed from a distance, that at a still somewhat higher level a lava stream might have emerged and flowed for some distance down a valley. All these eruption points seem to line up roughly in a north-south direction.

b) **Acatenango - Fuego**

This group of volcanoes forms a beautiful example of the cross-fault type of alignment. Photograph 2 shows this complex

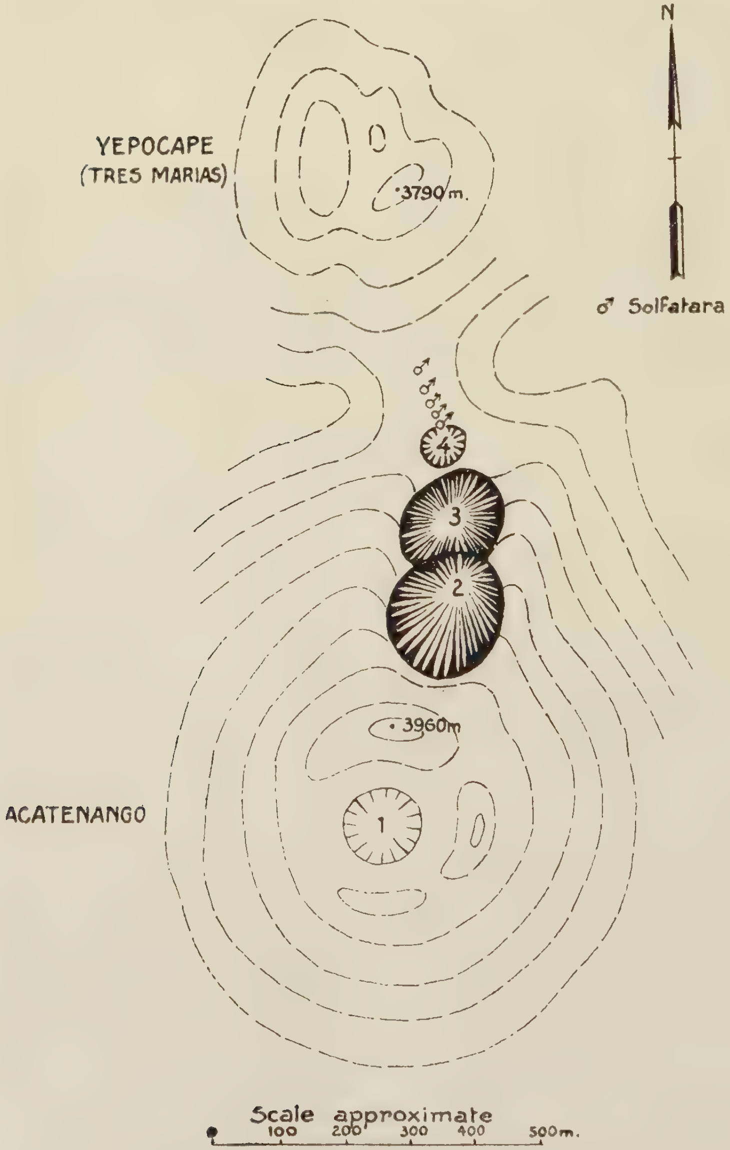

Fig. 3. — Sketch map of summit of Acatenango (March 1938).

from a northeasterly direction. From right to left we see first the Yepocape, then the Acatenango with small explosion craters on the north flank. Further left we see the « Meseta », a relic of an older volcano, which forms a shoulder to the presently active Fuego.

The summit of the Yepocape (or Tres Marías), about 3790 m high, shows a very shallow depression with a gully towards the north on its summit (see fig. 3 also left foreground of photograph 3) which is covered with ashes and debris from younger eruptions. The linear arrangement of the eruption points of the youngest activity is clearly to be seen in the three craters (4, 3, 2) leading upwards towards the main summit of the Acatenango. In reality this arrangement is still more impressive by the presence in the saddle between Yepocape and the Acatenango of a row of 4 solfataras, which appear as a white line leading in a direction of N 165° E straight to the lowest explosion crater (4). These solfataras are the remnant of a fissure which is clearly visible on the photograph of 1924, accompanying SCHMOLCK's article (p. 74). The three craters are funnel-shaped and their alignment curves slightly towards the south to the main summit of Acatenango. They were active during the eruption of 1926. Only ash was produced covering the saddle between Yepocape and Acatenango with a layer of about 1 m thickness. It was a gas eruption of small intensity and for details we refer to SCHMOLCK's paper.

The main crater (1) of Acatenango is formed by a shallow basin about 250 m in diameter, the bottom of which is some 40 metres below the highest summit. It is filled with ash and lapilli.

Acatenango and Fuego are separated by a saddle (about 3420 m).

DOLLFUS and DE MONTSERRAT recognized the Meseta already as being a volcanic ruin. In the field one clearly gains the impression that the presently active crater of the Fuego is situated excentrically to, and to the south of, a much older volcano, the topmost eastern part of which has disappeared. The shoulder-like ridge called « Meseta » forms a relic of the west rim of this old crater. This follows, as can be appreciated from

photograph 4, from the conical distribution of the tuff layers in the ravines of the steep east flank of the Meseta, apparently dipping away from a point somewhere in this flank.

By comparison of DOLLFUS and DE MONTSERRAT's description of the volcano as observed by them during their ascent in 1866 and a careful study of Fairchild's aerial photographs one obtains a fairly clear picture of the changes brought about

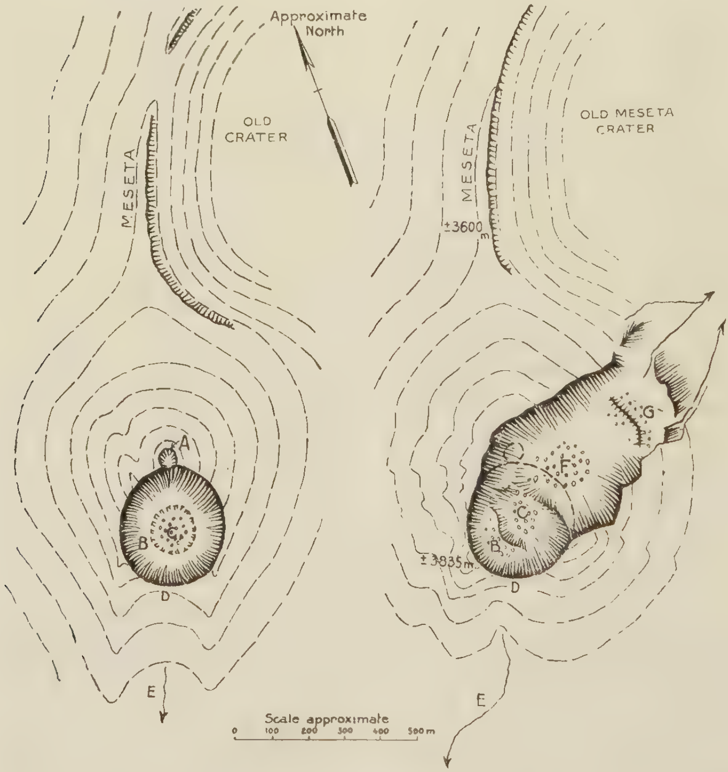

Fig. 4 *a* Fig. 4 *b*

Fig. 4 *a*. — Sketch map of summit of Fuego in 1866 after *Dollfus* and *De Montserrat*.

Fig. 4 *b*. — Sketch map of summit of Fuego in 1938.

by the last eruptions of 1888 and 1932. We have copied DOLLFUS and DE MONTSERRAT's schematic sketch of the crater in 1866 (fig. 4*a*). These Frenchmen reached the main summit from

the north by climbing the slope which leads from the Meseta upwards. This summit consisted of a small crater (A) with a diameter of some 50 metres and about 25 metres deep. About 30 metres before reaching the summit they met with 4 to 5 metres of bedrock composed of a reddish to purplish trachitic porphyry. We believe that this may have been connected with the conspicuous rocks visible in the right lower corner of photograph 5.

A breach on the S side of the small crater opened towards a tremendous and deep, roughly circular hole with an estimated diameter of 400 to 450 m (B). The vertical rock walls surrounding this ended below as a funnel into a deeper hole (C) with a diameter of about one hundred metres. The surrounding walls were lowest on the southern side of the main crater and opposite the highest summit. Here between two peaks a fairly flat low ridge existed forming the outlet of the crater (D), to the south of which a gully (E) originated on the outer slopes of the mountain, leading further downward into the Rio Achiguate. The old outlet can still be recognized on the aerial photographs, but carries at present a sharp ridge of tuff and ash (D, photograph 5 and between the two present main summits on photograph 6).

Reverting now to the crater as it appears today we might refer to the schematic sketch (fig. 4*b*) indicating the changes since DOLLFUS and DE MONTSERRAT's visit. This sketch is based purely on a study of the aerial photographs, since at the time of our ascent in 1938 the wind was adverse and therefore we had no view into the crater itself. During one of the eruptions of 1888 or 1932 a second vent (F) must have originated to the northeast of the old one, thus destroying the northeast segment of the old crater wall. As a consequence the outlet of the crater, which as we have seen above was first directed to the south (D), is now directed to the northeast in the direction of the village of Alotenango. The principal summit with the small crater of DOLLFUS and DE MONTSERRAT (A, fig. 4*a*) has disappeared.

On photograph 5 we recognize within the crater 3 patches covered with loose blocks or scree. The highest one (B) might be explained as being a mass of loose material resting on a

remnant of the old larger crater B (fig. 4*a*). This same mass of blocks can be recognized on photograph 4. The almost circular hole filled with blocks below the previous one on photograph 5 is most probably the deep circular hole C of fig. 4a. A sharp, very steep ridge, somewhat lighter coloured on the photograph separates this old vent from the youngest crater (F), the bottom of which is again filled with blocks and loose material as can be appreciated near the lower edge of the picture. The ridge separating the old and new craters can clearly be recognized on protograph 4 where it is in the shade. On this same photograph we see the deep breach in the crater wall towards the camera, so that we look straight into the new crater, with the old crater right behind it. It is also clear that the last eruption giving rise to the new crater must have been chiefly explosive, since apparently only the ruin of the old Fuego crater is left and only comparatively little recent material has been deposited. As such only the low tuff and ash ridge on the northeast side in the breach comes into consideration (G, photographs 6, 7). It should be noted that the rocks immediately below this breach show dips towards the south and SE and therefore belong to the Meseta volcano and not to the Fuego proper, as can be seen on photograph 7 (H).

A Swiss teacher, Mr Peter, who ventured on the Meseta during the last eruption of 1932, was struck by the fact that the mountain showed a fairly regular explosive activity at intervals which he estimated at about 5 minutes. In connection herewith we have studied the seismograms recorded at the Observatorio Nacionál in Guatemala City, situated some 40 km from the mountain. On the day of the eruption, January 21 st, 1932, many minor tremors were registered, supposedly of a volcanic origin but a clear regularity could not be recognized. Only between 13 h 39 and 15 h 38 fairly regular shocks occurred with intervals mostly between 4 to 7 minutes.

Fuego was already active when the Spaniards conquered Guatemala in 1524 and has remained so till today, with longer or shorter periods of quiescence. In 1938 it showed a fairly strong solfataric activity.

c) **Agua**

This solitary, almost perfectly regular conical volcano with an altitude of 3752 m (photographs 8, 9) has a small crater on its summit. To the NNE a small section of the crater wall is missing. The volcano has not been active in historic times.

d) **Pacaya**

East of the Agua a small group of volcanic mountains commonly known as the Pacaya draws the attention. DOLLFUS and DE MONTSERRAT visited this mountain and have described it. However, the sketch given by these authors (Planche 12, 13) does not quite agree with the impression obtained during the several ascents we made to this beautiful and interesting mountain group. We therefore believe it useful to give a new description, although no eruption has taken place since the visit of the French scientists. We refer to the sketch map fig. 5 which is based on some bearings and sketches made in the field but, lacking any proper surveying instruments, is not true to scale and gives only a subjective impression.

In 1938 the little hamlet of Calderas could be reached by car from Lago de Amatitlán. The road climbed the northern slopes of the Pacaya group and reached through a fairly sharp pass a large caldera. The bottom of this basin is in the north partly filled by a lake whereas the scattered huts and gardens of the village lie mainly to the south of it. It appeared as if the southeastern half of the caldera is covered under debris or deposits derived from the high summits to the southeast and east. In the steep rock walls to the north and east of the lake some very weak fumaroles were still observed (1938), whilst in the SW part of the caldera a small crater-like depression existed with fumaroles and faint solfataric activity. This last mentioned hole seemed located near the inner edge of the caldera as indicated on fig. 5. From near this small crater a path leads towards the saddle between the two highest peaks of the Pacaya mountain. Immediately NE of this saddle another sink-hole-like depression exists, which is completely overgrown like the ridge leading towards the jungle clad eastern summits which we have not investigated.

The southern summit, however, is again composed of some superimposed volcanic phenomena. Here the oldest feature is a semi-circular crater wall, open towards the southwest. On the

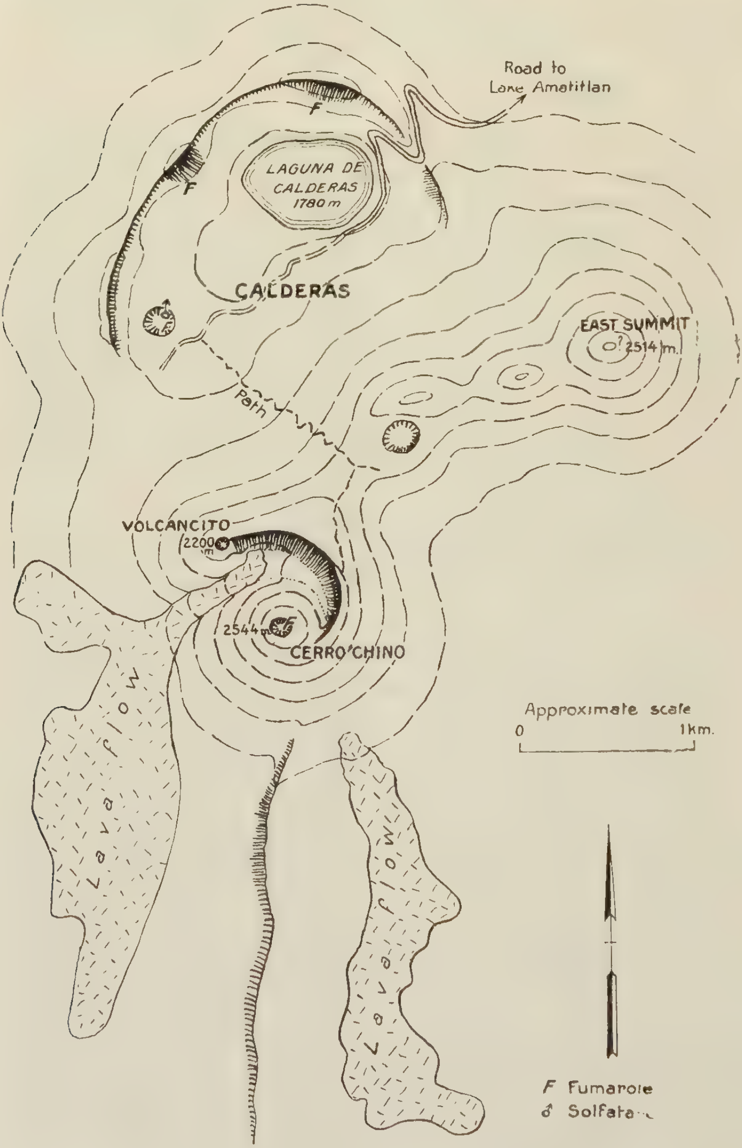

Fig. 5. — Sketch map of Pacaya massif.

inner edge of this old crater younger volcanic activity took place. We refer in the first place to the « Cerro Chino » (2544 m), a young and clear volcanic cone forming the highest point of the Pacaya mountain. It has a clear crater on its summit with many fumaroles. This volcano is situated excentrically within the older one and occupies the major part of the old crater floor with the exception of an excentric hornshaped valley. The southern end of the old crater wall is completely covered by the products of Cerro Chino. At the west end of the old crater wall occurs a very small and apparently young volcano «Volcancito» («El Hoyo» - Dollfus and De Montserrat), the crater rim of which is inclined towards the inner side of the main crater. Volcancito apparently did not produce a large quantity of ash and tuffs, so that it hardly exceeds the old crater rim in elevation. We suspect that it is connected with a fair-sized lava stream which had its origin at the foot of the old crater wall almost below Volcancito and which can clearly be recognized through its dark colour as if a stream of ink was poured out over the country to the south and southwest. Another lava stream is visible to the SSE of the Cerro Chino. It flowed out at a point near the foot of the mountain and a dike-like ridge can still be seen there.

According to tradition Cerro Chino originated during the eruption of 1565. The lava was probably produced during the 1775 eruption.

e) Lakes of a volcanic origin

It is almost inevitable that at this stage it is the majestic conical mountains which particularly attract the attention. However, if our knowledge of the country were further advanced no doubt many less conspicuous and even more interesting phenomena of a volcanic nature would be recognized. We might refer to the origin of various lakes, the most famous of which, Lago de Atitlán, has already formed the subject of a controversy as will be discussed below.

We first, however, wish to draw attention to a few other lakes with a possible volcanic origin. A very small one is situated about 15 km north of the City of Guatemala and north

of the village of San Antonio las Flores. The lake is located in a semi-circular recess in the east flank of the valley of the Rio de las Vacas and above the bottom of this valley. A ridge of andesitic lava blocks dam the lake. The mountains in the immediate surroundings consist of coarse crystalline porphyritic granite, capped by tuffs and blocks of an andesitic to dacitic composition, as can clearly be observed north of San José Nacahuil. Tentatively we might explain this lake as being a crater left by an explosion which produced very little volcanic material, possibly only the lava blocks on the shore of the lake. Similar lakes have been mentioned by VON WOLFF, e. g. the Laguna de Retana, to the west of the Suchitán, and the Laguna del Hoyo, north of the Tahual.

Lago de Ayárza, located some 10 to 12 km SSE of Mataquescuintla suggests, on account of its larger size, a more powerful explosion. It could perhaps be a caldera, the remnant of one (or two) large volcanoes which have been blown up. In the neighbouring republic of El Salvador, Lago de Coatepeque as seen from an aeroplane gives a strong impression of being such a caldera. Many others undoubtedly exist in Guatemala, although they may not or only partly contain a lake. We might mention in this respect Siete Orejas, with no lake but having a caldera of some 3 by 5 kilometres according to SAPPER, Lago de Calderas on the Pacaya, referred to above, a. o. Finally we should mention still Chicaval, which is a crater filled by a lake.

f) **Lake Atitlán**

We now revert to the most famous and beautiful of Guatemalan lakes, Lago de Atitlán, 26 km long, 18½ km broad and 320 m deep. To the north, east and west it is surrounded by mountains which rise rather steeply out of the lake. The south shore, however, is mainly formed by the gently sloping foot of two volcanoes, Tolimán and San Pedro. This state of affairs gives, of course, at first glance the impression that the volcanoes dammed the normal outlet towards the Pacific Ocean and thereby brought the lake into existence. This is the oldest theory of the origin of the lake, proposed by DOLLFUS and DE MONT-

SERRAT (1868). However, the shape of the lake is not in correspondence with what one would expect of a flooded basin formed through normal erosion. Even if the volcanoes did not exist and the lake was empty a remarkable steep depression would remain in the general morphology. ANDERSON (1908), therefore, suggested that the lake represented an enormous caldera. WEBSTER MC BRIDE (1933) accepted Anderson's idea, but believed that, instead of one volcano, several occurred in the place now occupied by the lake.

If this assumption were correct we would expect still to find some remnants of the foot of these vanished volcanoes in the form of an outward sloping ridge around the lake. This is not the case and the somewhat undulating, fairly flat, dissected tuff plateaux, occurring for instance to the east of the lake, seem to be cut off rather suddenly, as can be seen on photograph 10. The more or less horizontal structure of these tuffaceous deposits can in several places be clearly recognized in the mountain slopes bordering the lake. Another phenomenon which does not agree with the caldera hypothesis is the fact that some truncated valleys can still be found along the lake, especially along the E shore (see the photograph 11), although most valleys show a very deep retrograde erosion. We are therefore in favour of trying to find another solution and in view of the steepness of the surrounding slopes, and the fairly young impression which the lake makes, we are tempted to suggest that this large depression has a relatively young and tectonic origin.

Lake Atitlán is, it appears to us, not the only case of its kind and off-hand we would like to mention the following cases for future critical examination. The plain of Quetzaltenango seems older in age than Lake Atitlán, since if a lake was present it has been completely filled up with sediments. It seems not impossible that this plain is bordered at least on its north side by faults which might follow the foot of the fairly steep slopes (e. g. north of Olintepeque) forming the southern boundary of the high plateau of Sija.

As a third possible case we might mention Lake Amatitlán, south of Guatemala City. Here the high tuff plateau on which the capital city is built is cut off abruptly to the south and it

seems that the north slope of the Pacaya volcanic massif rises again rather gently from the lake in a southern direction. Maybe the history of this lake is more complicated since it appears, as seen from a distance, and especially from the north (e. g. from the highway to San Salvador), as if the hills east of and above the village of Rincón might represent the remnant of the foot of a volcano which once existed in the eastern end of the lake.

In all these cases it looks as if a more or less half circular segment open towards the Pacific may have subsided. Conspicuous volcanoes occur to the south of the possible subsided segments; south of the plain of Quetzaltenango: Siete Orejas, Cerro Quemado and Santa María, south of Lago de Atitlán: San Pedro - Santa Clara and Tolimán-Atitlán, south of Lago de Amatitlán: the Pacaya group. We are therefore tempted to search for a causal relation.

It thus seems to us that we might possibly have to deal with a rather frequent phenomenon and we whould be happy if the above remarks would stimulate further investigation.

LITERATURE

T. ANDERSON. *The Volcanoes of Guatemala.* Journ. Geogr. Soc. London, Vol. XXXI, 1908, p. 482.

A. DOLLFUS et E. DE MONTSERRAT. *Voyage géologique dans les Républiques de Guatemala et de Salvador.* Paris 1868.

W. Q. KENNEDY and J. E. RICHEY. *Catalogue of the active volcanoes of the world.* Bulletin volcanologique de l'Ass. de Volc. Union géod. et géoph. intern. Suppl. de serie II, Tome VII, 1947.

W. MCBRIDE. *Sololá.* Tulane University of Louisiana. New Orleans 1933.

S. POWERS. *Notes on the geology of eastern Guatemala and northwestern Spanish Honduras.* Journ. Geol. Vol. 26, 1918, p. 507-523.

J. L. REYES. *Datos geográphicos y Estadísticos de la Republica de Guatemala.* Anales Soc. Geogr. e Hist. Guat., Tomo XIII, 1936, p. 202-215.

K. SAPPER. *Die Vulkanische Ereignisse in Mittelamerika im Jahre 1902*. Neues Jahrb. f. Min. etc., 1904, Bd. 1.

——— — *In den Vulkanbergen Mittelamerika's und West-Indiens*. Stuttgart 1905, p. 110 sq.

——— — *Reise nach Süd- und Mittel-Amerika*. Mitt. Geogr. Ges. Würzburg, Bd. III-IV, Jahrg. 1929.

——— — *Mittel-Amerika*. Handbuch Reg. Geol., Bd. VIII 4ª Heidelberg 1937 (with extensive literature).

K. SAPPER and F. TERMER. *Der Ausbruch des Vulkans Santa Maria in Guatemala vom 2-4 November 1929*. Zeitschrift f. Vulcanologie, 1930, Bd. XIII, p. 73-100.

F. H. SCHMOLCK. *Actividades del Volcan de Acatenango en 1926*. Anal. Soc. Geogr. e Hist. Guat., Tomo VII, 1930, p. 62-68.

C. SCHUCHERT. *Historical geology of the Antillean Caribbean Region*. New York, 1935.

L. WAIBEL. *Die Sierra Madre de Chiapas*. Geogr. Gesellsch. Hamburg Mittl. Vol. 43, p. 12-162 (1933).

F. VON WOLFF. *Der Vulkanismus*. II. Band, 1. Teil. Stuttgart, 1929.

Photo Fairchild Aerial Surveys Inc.

Photo 1. — The volcanoes south of Lake Atitlán from the WNW.

Photo Fairchild Aerial Surveys Inc.

Photo 1. — The volcanoes south of Lake Atitlán from the WNW.

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Photo 2. — Acatenango and Fuego from the NE.

Photo 3. — Summit of Acatenango from the NNW.

Photo Fairchild Aerial Surveys Inc.

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Photo 4. — Fuego and Meseta from the NE.

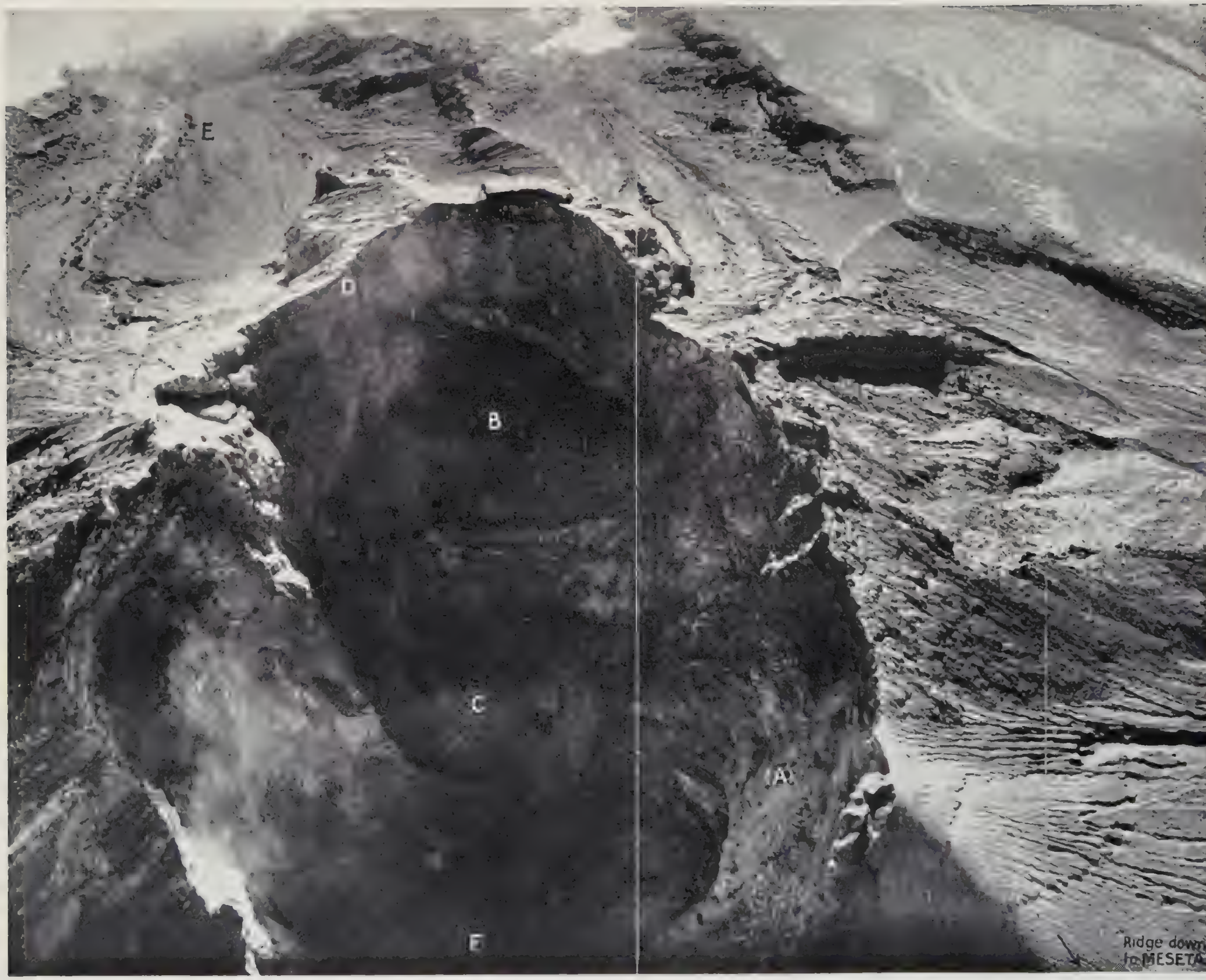

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Photo 5. — Crater of Fuego seen under a steep angle towards the SE.

Photo 6. — Summit of Fuego from the N.

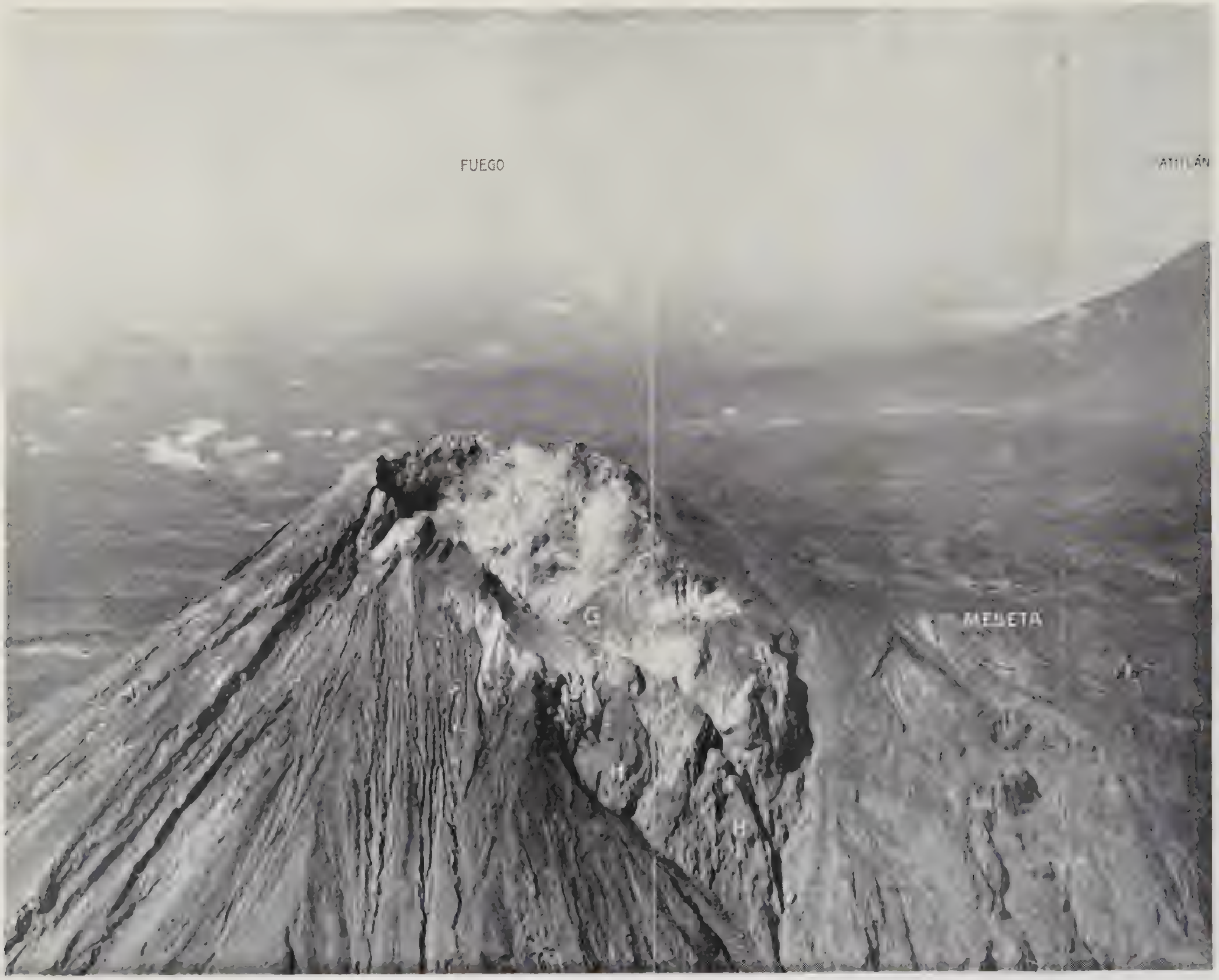

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Photo 7. — Summit of Fuego from the E.

Photo Fairchild Aerial Surveys Inc.

Photo 8. — Agua, Fuego and Acatenango from the E.

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Photo 9. — Agua from the WNW.

Photo J. Schwendener

Photo 10. — View from Finca Chixoy towards lake Atitlán. From left to right volcanoes Atitlán, Tolimán and San Pedro.

Photo J. SCHWENDENER

Photo 11. — Lake Atitlán from a point near Godinez. The mountain in the left background shows truncated valleys. Foreground on the shore of the lake the village of San Antonio Palopo. Background volcanoes Atitlán and Tolimán.

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Prediction in relation to Seismo-volcanic Phenomena in the Caribbean Volcanic Arc

(With 2 Figures)

CONTENTS

Introduction

Observations and inferences made in Martinique and Montserrat (Lesser Antilles) by Mr. F. A. Perret and others from 1929 to 1937, and by Dr. C. F. Powell and the writer in 1936, have suggested the compilation of a review of evidence potentially useful for predicting the time and place of future earthquakes, soufrière activity or volcanic eruptions in this part of the West Indies.

The objects of the following notes are: 1) to summarise facts relating to seismo-volcanic disturbances in the Caribbean region (with special reference to the Caribbean volcanic arc: Fig. 1) and inferences drawn from them; 2) to indicate exactly where scattered records of facts and inferences are to be found in the literature, additions to which during the last dozen years include three un-indexed monographs each exceeding seventy pages in length (Perret 1935, 1939; MacGregor 1938). The summary

includes accounts of premonitory symptoms known to have heralded eruptions at various centres.

The methods developed by Mr. PERRET for « feeling the pulse » of an active volcano, as applied in particular to Montagne Pelée (Mt. Pelée or Mt. Pelé) in Martinique (PERRET 1935, pp. 8-14), will be referred to only so far as they concern general seismo-volcanic conditions in the Caribbean volcanic arc.

The circumstances that gave rise to the work of Mr. PERRET, Dr. POWELL and the writer in Montserrat are as follows. This island experienced a series of local « volcanic » earthquakes of considerable violence, accompanied by abnormal soufrière activity, from 1897 to 1899. Disturbed conditions are said to have lasted until 1902 (MACGREGOR 1938, p. 6; PERRET 1939, p. 64), but they were not renewed after the great eruptions of the Soufrière of St. Vincent and of Mt. Pelée in Martinique, which began almost simultaneously in that year. Towards the end of 1933 there was a renewal of local earthquakes in Montserrat, again accompanied by increased soufrière activity. In 1934 and 1935 the frequency of the shocks (some of which were violent and caused much damage), and the abnormal gas-emission from the soufrières, gave rise to anxiety. Mr PERRET visited the island in 1934 and 1935, submitted to the Governor of the Leeward Islands a number of valuable reports, and initiated continuous observational work. In 1936, the Royal Society sent Dr POWELL and the writer to continue and extend Mr. PERRET's study of the nature and location of the earthquake shocks and of the conditions at the soufrières, and to work out the morphology and volcanic history of the island. In 1936, earthquakes and soufrière activity were on a much reduced scale, and the decline of activity continued.

Evidence of earthquakes

The Caribbean Region as a whole.

TEMPEST ANDERSON and FLETT mention records of earthquakes and volcanic eruptions that led them to believe there is some kind of interconnection between volcanic activity in the Lesser Antilles and major earthquakes in other parts of the

Fig. 1 — Map of the Caribbean Volcanic Arc

Caribbean region, including the Greater Antilles and the Central American mainland (1).

For instance they cite records (mainly from HUMBOLDT) of the approximate contemporaneity of (*a*) a great earthquake in Jamaica, and the eruption of Mt. Misery in St. Kitts, in 1692; (*b*) earthquakes in Venezuela, Trinidad, Jamaica, etc., and the eruption of Qualibou volcano in St. Lucia in 1766; (*c*) great earthquakes in Ecuador and Venezuela, and the eruption of the Soufrière volcano in Guadeloupe in 1796/7; (*d*) a violent earthquake in Venezuela, and the eruption of the Soufrière volcano in St. Vincent in 1812; (*e*) many earthquakes in the Greater Antilles, and the eruption of the Grande Soufrière volcano in Dominica in 1880; (*f*) a violent earthquake in Guatemala in 1902, just before Mt. Pelée began to emit steam.

The duration of the eruptive activity in Martinique and St. Vincent in 1902 (exceptionally prolonged when judged by previous Caribbean standards) was attributed to the continuation of crustal adjustments affecting the whole border of the Caribbean Sea (ANDERSON and FLETT 1903, pp. 533-4).

It is clearly desirable that critical and authoritative documented statements should be prepared, in order to compare the dates, locations, and degrees of violence of all seismic, fumarolic and volcanic activity known to have occurred in the Caribbean region in historic times. Such a compilation, made from all available original records, would involve a lengthy piece of research in European libraries and in Caribbean archives. A provisional graphical compilation for the Caribbean volcanic arc (up to 1938), based only in part on original records, is provided in Fig. 2; it is discussed in a later section of this paper (pp. 79-82).

Martinique and St. Vincent.

Before the 1902/7 eruption of Mt. Pelée in Martinique, the submarine cable to Guadeloupe was broken on 22 April; the rupture may or may not have been due to seismic activity (2).

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(1) See also p. 77 for examples of contemporaneity of eruptions throughout the Caribbean region.

(2) The prolonged eruptions of Mt. Pelée and of the Soufrière of St. Vincent which began almost simultaneously early in May 1902, were accompanied by the repeated rupture of all submarine cables west of the

Slight earthquake shocks occurred, however, on the western flanks of the volcano on 23, 25 and 30 April, that is to say about the time of *initiation* of explosive phenomena on 24 April. During the eruptions, earthquakes did not coincide with explosive paroxysms (Lacroix 1904, pp. 35, 90).

Before the 1929/32 eruption of Mt. Pelée, the records of seismic activity at the volcano observatory on Morne des Cadets showed no abnormality in the number and intensity of tremors. In September and November of 1928, however, seismograph records resembling those produced by mine-explosions had been obtained; it is thought that these tremors may have been connected with the internal activity of the volcano (Romer 1936, p. 92).

In the twelve months before the eruption of the Soufrière of St. Vincent in 1812, over 200 earthquake shocks were counted in the island (Anderson and Flett 1903, p. 533).

A series of earthquakes in St. Vincent in 1901/2 proved to be a premonitory symptom of the eruption of 1902/3. In February and March 1901 tremors became much more numerous than usual on the north side of the Soufrière volcano. Shocks continued for the ensuing twelve months; they increased in number and in violence in the latter part of April 1902, that is to say shortly before the initiation of eruptive activity on 6/7 May. Severe local shocks recurred during the eruptive period, and were sometimes contemporaneous with explosive activity at Mt. Pelée (Anderson and Flett 1903, pp. 378-9, 532-5).

Montserrat.

The earthquakes of the years 1933 to 1937 in Montserrat proved to be mostly of shallow origin, the majority of the foci being below the island and between one and two kilometres from the surface (MacGregor 1938, pp. 14-5; Powell 1938, Fig. 11 and p. 31; Perret 1939, pp. 26-8, 48, 58).

The seismic disturbances were of volcanic origin, that is to say intimately connected with local soufrière activity (see p. 74) and general magmatic conditions along the Caribbean volcanic arc. Mr. Perret regarded the earthquakes as « subvolcanic »

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two volcanoes. The causes, or cause, of the ruptures are not clear (Lacroix 1904, pp. 92-107).

(MacGregor 1938, pp. 14, 39, 83; Powell 1938, pp. 28-32; Perret 1939, pp. 2, 19, 36-7, 47-9, 53-4, 62, 72).

Dr Powell's map of the distribution of earthquakes in Montserrat in 1936 shows an elongated clustering of epicentres (Region II) that is almost coincident with a line of soufrières mapped by the writer. This suggested that here the earthquake and soufrière activity was connected with a plane of crustal weakness or of deep-seated fracture (Powell 1938, Fig. 11; MacGregor 1938, pp. 14-5, 40). Mr. Perret also connected the earthquakes with crustal fractures, but his views on the origins of the earthquake and soufrière activity differ considerably from those of Dr Powell and the writer (Perret 1939, Fig. 3 and pp. 36, 48, 57, 72).

The foci of the 1936 earthquakes in Montserrat were distributed beneath parts of three of the seven volcanic centres of the island, including the youngest (Powell 1938, Fig. 11). This distribution might perhaps have been used as evidence that no local eruption was imminent; for had such been the case epicentres would more probably have been confined to the area occupied by the Soufrière Hills, the youngest volcano and the only one with active soufrières on its flanks.

One of the earthquakes (10 November 1935) was recorded over a large part of the world (Powell 1938, pp. 26, 31). After this major shock, the epicentre of which was north of Montserrat, seismo-volcanic disturbances in the island began to decline; in 1936 the shocks were fewer and much less violent than in 1934 and 1935, and the decline in activity continued. This suggests that a major shock in a series of local volcanic earthquakes may be a sign that the peak of activity has passed (Powell 1938, pp. 26-9, 32; MacGregor 1938, p. 15).

Evidence of soufrière activity

Martinique and St. Vincent.

Premonitory symptoms of the eruption of Mt. Pelée in Martinique in 1902/7 were apparent, it is said, as early as 1889, when small hydrosulphuric fumaroles appeared in the crater. In 1900, in 1901, and in February 1902 increases in soufrière

activity were observed; explosive phenomena began on 24 April 1902 (LACROIX 1904, p. 34).

In the case of the eruptions that began at Mt. Pelée in 1929, the only warning appears to have been a slight increase in the number and activity of the fumaroles on the dome of 1902/7. These soufrières showed signs of increased gas-emission in March and May 1929, and began to emit sulphur dioxide instead of (or in addition to) hydrogen sulphide on 23 August 1929; this was about a month before the commencement of explosive phenomena, which at first were mild (ROMER 1936, pp. 89, 92, 115).

In relation to St. Vincent before the eruptions of 1902/3, there are apparently no records concerning soufrière activity. According to Dr. JAGGAR, the water in the crater lake was noticed to be warm in January 1902 (ANDERSON and FLETT 1903, p. 532).

Montserrat.

During the seismo-volcanic « crisis » in this island in 1933/37, it was found that temporary intensifications of soufrière activity coincided with « seismic storms » of the earthquake series (MACGREGOR 1938, pp. 39, 83; PERRET 1939, pp. 19, 37, 62, 72). According to Mr. PERRET, increased gas-emission at the soufrières was the only normal presage of a considerable shock; but a severe shock occurred without such a premonitory symptom (PERRET 1939, pp. 58, 62); moreover, increased gas-emission did not always herald a shock or shocks (PERRET 1939, Fig. 20).

The gas-emission, although abnormal in pressure and quantity, remained normal in type (mainly hydrogen sulphide (1) and steam), and soufrière temperatures remained low from a volcanological point of view-close to the boiling point (of water) corresponding to the barometric pressure. These facts, and the continued absence of acid gases such as sulphur dioxide, hydrogen

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(1) Mr. PERRET believes that eye-stinging gaseous polysulphides of hydrogen were also emitted at the soufrières, and that they were decomposed into hydrogen sulphide and sulphur at a distance from their points of origin. He also recorded carbon dioxide in comparatively small quantities (PERRET 1939, pp. 42-5, 72).

fluoride and hydrochloric acid, were regarded as indicating that a local eruption was unlikely (POWELL 1937, pp. 490-1 ; MACGREGOR 1938, pp. 39-46, 84; PERRET 1939, pp. 36, 41, 43, 46, 72).

Significance of peléean domes in volcano craters

According to Mr. PERRET, dome-building (accompanied by the production of *nuées ardentes*) marks a late, decadent, stage in the evolution of a volcano such as Mt. Pelée, characterised by acidic lava, and this fact is valuable in volcanological diagnosis and prediction (PERRET 1935, p. 106, 112). The duration of such a late phase, although short from a geological point of view, may be protracted when regarded from the human standpoint. Thus, at Mt. Pelée, the explosive dome-building of the 1902/7 eruptions was renewed during 1929/32, *though on a less catastrophic scale*; and it may well recur. The Soufrière of Guadeloupe, according to HOVEY and LACROIX, has a crater containing a pre-historic peléean dome (LACROIX 1904, p. 56; 1908, p. 60). Several eruptions of minor character have occurred since 1696. But, because there have been no very violent eruptions during this long period, it may be argued that the volcano supports PERRET's generalisation (MACGREGOR 1938, p. 85).

HOWEL WILLIAMS, in commenting on a similar generalisation made earlier by FRIEDLAENDER and by POWERS, states that it is subject to « many exceptions »; he does not analyse these exceptions, and names only one of the volcanoes concerned - Saishu in Japan (WILLIAMS 1932, p. 146). From his account of Saishu, it seems likely that some, at least, of WILLIAMS's « many exceptions » concern recrudescence of activity *not at the same volcano* but at other eruptive centres in the vicinity (WILLIAMS 1932, p. 99). It is also possible that other important factors, such as the time and the violence of the recrudescence, are not comparable in all the exceptions that he has in mind.

Castles Peak in Montserrat was found to be a peléean dome in the breached crater of an eroded volcano which, apart from

soufrière activity on its flanks, has been inactive since 1493, and probably for a much longer period (MacGregor 1938, pp. 28-30, 83). This volcano (Soufrière Hills) is the youngest in the island, and its eruptions were proved to have been predominantly of *nuée ardente* type (MacGregor 1938, pp. 30-4); petrologically its rocks closely resemble those involved in the 1902/7 and 1929/32 eruptions of Mt. Pelée (MacGregor 1938, p. 72). In view of Mr. Perret's generalisation, and of the Guadeloupe evidence, the writer inferred that, in Montserrat, a renewal of violent explosive activity was improbable (MacGregor 1938, p. 85).

Because a dome has not yet formed in the crater of the Soufrière of St. Vincent, Mr. Perret has stressed the probability that this volcano may still retain a great store of potential energy. He points out: 1) that conditions at the Soufrière of St. Vincent are not fully comparable with those at Mt. Pelée before the dome-building of 1902, because the lava of the Soufrière is of a rather more basic character; 2) that, nevertheless, activity in St. Vincent in 1902 was of an explosive type having much in common with that of Mt. Pelée (1). Mr. Perret therefore considered it probable that a dome will eventually form in the crater of the Soufrière of St. Vincent, where eruptions have occurred at intervals of about ninety years since 1718. (Perret 1935, pp. 112, 115; 1939, p. 34, Fig. 1, and p. 2). Few volcanologists are likely to disagree with this prediction.

Records indicating short-term « Periodicity » of seismo-volcanic phenomena at local centres of disturbance

Records of earthquake and related soufrière activity in Montserrat from 1933 to 1937 (e. g. Perret 1939, Fig. 20), when considered in relation to the succession of events during previous volcanic episodes in St. Vincent and Martinique, and elsewhere in the Caribbean region, indicate that, in the Caribbean volcanic arc, seismo-volcanic disturbances tend to be part-

(1) For a summary of current opinions regarding the mechanism of various types of *nuée ardente* eruptions at Mt. Pelée, at the Soufrière of St. Vincent, and elsewhere, see MacGregor 1946, p. 305.

icularly violent at certain periods of the year - early in May and between October and December (1). The evidence is as follows.

The most violent outbursts of the 1812/14 eruption of the Soufrière of St. Vincent were at the beginning of May (LACROIX 1904, p. 47). The major paroxysms in St. Vincent and Martinique in 1902 occurred on the 7 and 8 May respectively (ANDERSON and FLETT 1903, p. 392; LACROIX 1904, pp. 49, 37). On 10 May 1902, Izalco volcano in Salvador renewed its customary activity after a fifteen months pause (SAPPER 1905, p. 82). In Montserrat, in 1934, 1935 and 1936, markedly increased earthquake and soufrière activity were experienced early in May (MACGREGOR 1938, p. 84; PERRET 1939, Fig. 20). As early as March 1935 MR PERRET successfully predicted that, if the bi-yearly crises of 1934 were to be repeated in 1935, it would be in May that stronger conditions would prevail (PERRET 1939, p. 27 and Fig. 20).

In commenting on Montserrat crises in May, the writer has pointed out that May was a critical period at Lassen Peak volcano in California, where the main eruptions of 1914/17 occurred in that month in 1914, 1915 and 1917 (MACGREGOR 1938, footnote p. 84).

The most violent activity of the 1851/2 eruption of Mt. Pelée occurred in late October to early November (LACROIX 1904, p. 32). During the Montserrat earthquake series of 1897 onwards, particularly strong shocks occurred in mid-October 1900 (PERRET 1939, p. 64). An outburst of considerable violence occurred at Izalco volcano in Salvador on 28 September 1902, following on the renewal of activity of 10 May of that year (SAPPER 1927, p. 127). At the Soufrière of St. Vincent, after the May eruption of 1902, the most violent recrudescence of activity was in the middle of October of the same year (ANDERSON 1908, p. 290). On 24 October 1902 a violent eruption occurred at the volcano of Santa Maria in Guatemala, which was believed to be extinct (SAPPER 1905, p. 82). At Mt. Pelée

(1) For a discussion of 1) the legitimacy of regarding this recurrence of events as « periodic », and of 2) a postulated lunisolar causation, see: LENOX-CONYNGHAM 1937, p. 908; PERRET 1939, pp. 62, 75 and Fig. 20.

in 1929-32 the most violent phase of the eruption began on 20 November 1929 (ROMER 1936, pp. 94-6, 115). In Montserrat, during the period 1933-36, peaks of earthquake and soufrière activity occurred in December of 1933 and 1934 and in November of 1935 (MACGREGOR 1938, p. 84; PERRET 1939, Fig. 20).

As regards the Caribbean volcanic arc (and other parts of the Caribbean region) it must not be inferred that minor disturbances or violent eruptions may not occur in the future, as they have in the past, at other periods of the year. In the volcanic arc serious eruptions have, for instance, taken place in March, and between 30 August and 31 September. Nevertheless it would clearly be most imprudent to ignore the fact that the beginning of May and the last quarter of the year (particularly October-November) have been periods especially liable to unrest (MACGREGOR 1938, p. 84; PERRET 1939, pp. 27, 62-4).

Records indicating oscillation of seismo-volcanic phenomena within the volcanic arc

The writer's « space-time » method of graphical representation of past records of seismo-volcanic episodes in the Lesser Antilles (Fig. 2) indicates that there has been a tendency for the centre of disturbance to oscillate back and forth along that part of the volcanic arc between St. Kitts and St. Vincent (cf. MACGREGOR 1938, Fig. 2 and pp. 6-7, 84). On the evidence provided by his original graphical record (1938 Fig. 2) the writer suggested (early in 1937) that the next manifestation of activity would probably be in Guadeloupe or St. Vincent or in one of the intervening islands, and that it would occur at an early date (MACGREGOR 1938, pp. 83, 85). A series of earthquake shocks occurred shortly afterwards in Dominica, an island between Guadeloupe and St. Vincent (PERRET 1938).

Records of long-term intervals between seismo-volcanic phenomena in the volcanic arc

Records of seismo-volcanic events in the Caribbean volcanic arc (1) mentioned by TEMPEST ANDERSON and FLETT, LACROIX,

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(1) Dr. T. A. JAGGAR, as an appendix to a report submitted to the Royal Society after his visit to Montserrat in 1936, gave a résumé of

SAPPER, VON WOLFF (1929), PERRET and ROMER were tabulated in 1937 (MACGREGOR 1938, p. 6 and Fig. 2). They led the writer to point out, in 1937, that 1) since 1692 the longest period that has elapsed without the occurrence of a seismo-volcanic disturbance somewhere in the arc is 47 years; 2) since 1766 the longest period of tranquillity (1) has been 28 years; 3) on seven occasions the interval between eruptions or minor volcanic activity has been seven years or less; 4) there is thus every reason to believe that eruptions or earthquakes will be renewed in the volcanic arc at no distant date, and probably more than once in the lifetime of the present generation (MACGREGOR 1938, pp. 83-4).

Mr PERRET has inferred from his own compilation of seismo-volcanic records in the volcanic arc (sources unspecified: PERRET 1929, Fig. 1) that there is a periodicity approximating to 30 years (or to some multiple of this such as 60 or 90) connected with a « magmatic expansion » which occurs about three times a century and gives rise to localised concentrated effects under and through the various previously formed island centres (PERRET 1939, p. 2).

The exact meaning of these statements is not clear to the writer. This is partly because Mr PERRET quotes in their support time-intervals between selected events in various islands, while ignoring eruptions etc. which occurred in other islands during the same periods (2). Time-intervals so computed do not seem to have a bearing on *periodicity*, either in the arc as a whole or in individual islands. Neverthless a tabular statement compiled by the writer (Table I: based on Fig. 2: see below) indicates that Mr PERRET has done a useful service in drawing attention to the tendency towards gaps approximating to 30.

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the seismic history of the West Indies in the preceding 250 years. This report is filed for reference at the Royal Society rooms.

(1) « Tranquil » years were reckoned from the end of the *last* year of one episode to the beginnning of the *first* year of the succeeding episode.

(2) In computing two of these intervals Mr. PERRET has made a slip in assigning an eruption at Qualibou in St. Lucia to the year 1756. Qualibou erupted in 1766, as recorded by himself in his table of seismo-volcanic events (PERRET 1939, Fig. 1). This eruption has also been recorded erroneously as having taken place in 1776 (ANDERSON and FLETT, 1903, p. 535).

60, or 90 years between the initiations of successive notable seismo - volcanic incidents *in individual islands*. There is an even greater tendency for gaps to approximate to a multiple of 15 years; but with so small a basic period the approximation is not close enough to be of much value for purposes of prediction.

Mr PERRET includes in his table of seismo-volcanic events a number of episodes of which the writer was unaware when he prepared the diagram for his 1938 paper (MACGREGOR 1938, Fig. 2); Mr PERRET omits, however, without comment, two records of submarine eruptions (between Guadeloupe and Marie Galante in 1843, and between St. Vincent and Barbados in 1831) and some minor events, all of which were recorded by the writer on the authority of previous publications. A new graphical space-time diagram of seismo-volcanic events in the Caribbean volcanic arc, up to 1938, has therefore been prepared, combining Mr PERRET's new data, from unspecified sources, with all events previously quoted by the writer (Fig. 2). In this graphical statement intervals between events are calculated from the *first* year of one episode (even though it be prolonged: e. g. Mt. Pelée 1902/7) to the *first* year of the next (e. g. Mt. Pelée 1929/32).

It will be seen from the last column of Fig. 2 that, if the volcanic arc is considered as a whole, there is no tendency for intervals approximating to 30, 60 or 90 years to occur between the initiation of successive eruptions; nor have eruptions occurred only three times a century since 1692, even if we ignore submarine eruptions, and the Montserrat disturbances of 1897/9 and 1933/7 which Mr. PERRET (1939, p. 2) appears to class as eruptive periods corresponding to magmatic expansions: see also under 1c), p. 83.

Consideration of all the evidence available leads to the following general indications of the seismo-volcanic prospects *in individual islands*, after a relatively serious episode, which need not necessarily include a volcanic eruption.

1) Recurrence of serious trouble within 12 to 15 years of a given incident will be most exceptional.

TABLE I

Island	Interval between seismo-volcanic incidents	Interval as approximate multiple of 30	Interval as approximate multiple of 15	Number of recorded intervals that do not approximate to multiples of 30 or 15
Montserrat	1897 - 1933 (36 years)	—	—	1 (36 years)
Guadeloupe	1837 - 1896 (61 years)	30 × 2	15 × 4	2 (103 and 38 years)
Dominica	1673 1765 (92 years)	30 × 3	15 × 6	None, but the approximation to 15 × 5 in the case of the 1809-1880 interval is poor.
	1765 - 1809 (44 years)	—	15 × 3	
	1809 - 1880 (71 years)	—	15 × 5	
	1880 - 1938 (58 years)	30 × 2	15 × 4	
Martinique	1727 - 1771 (44 years)	—	15 × 3	4 (70, 23, 12 and 24 years)
	1771 - 1816 (45 years)	—	15 × 3	
	1851 - 1878 (27 years)	30 × 1	15 × 2	
	1902 - 1929 (27 years)	30 × 1	15 × 2	
St. Lucia	1766 - 1906 (140 years)	—	—	1 (140 years)
St. Vincent	1718 - 1812 (94 years)	30 × 3	15 × 6	None
	1812 - 1902 (90 years)	30 × 3	15 × 6	

2) There is a good prospect of between 23 and 30 years of freedom from serious disturbance.

3) If there has been no recurrence of trouble after 30 years, the approximate time of the initiation of the next danger period is likely to be after an *additional* 6 to 8, 15, 30, 40, or 60 to 65 years, or after an even longer period.

It is hardly necessary to say that too much reliance should not be placed on such generalisations. In the writer's opinion, however, they will definitely serve a useful purpose in giving a general idea of the future probabilities of seismo-volcanic troubles throughout the Lesser Antilles: see also under 1d), p. 83.

In assessing the prospects of the nature and violence of future disturbances at any one centre, not only must the past records of the island concerned be considered, but also the age and structure of its volcanoes and the oscillation-phase of the migration of disturbances along the volcanic arc.

Summary of evidence and inferences

This paper summarises facts relating to seismo-volcanic disturbances in the Caribbean region, and brings together evidence used by Mr F. A. PERRET, Dr C. F. POWELL and the writer for prediction in relation to such disturbances in the Caribbean volcanic arc of the Lesser Antilles. Facts and inferences may be summarised as follows.

1) Historical records of seismo-volcanic events in the Caribbean region indicate that. —

a) The beginning of May and the last quarter of the year (particularly October-November) are periods at which especially violent seismo-volcanic events are liable to occur (PERRET, POWELL, MACGREGOR).

b) There is a tendency for the main centre of disturbance to oscillate back and forth along that part of the Caribbean volcanic arc between St. Kitts and St. Vincent. The phase of the oscillation gives some indication of the most likely locus of the next disturbance (MACGREGOR).

c) Since 1657 volcanic eruptions have occurred at different places in the Caribbean volcanic arc at intervals ranging from 4 to 48 years. On six occasions the interval between the initiation of successive sub-aerial eruptions has been between 22 and 31 years. If records of strong earthquakes, of earthquake series, and of submarine eruptions are taken into account, the interval between the initiation of seismo-volcanic disturbances has on nine occasions been 4 years or less, on five occasions between 15 and 17 years, on four occasions between 23 and 28 years, and on one occasion 38 years (MacGregor).

d) On any one island in the Caribbean volcanic arc there has often been an interval of at least 23 to 30 years between the initiation of one relatively serious seismo-volcanic disturbance and the beginning of the next. Intervals of *about* 8, 12, 37, 45, 60, 70, 92, 103 and 140 years have also been recorded in different islands (MacGregor).

e) Some idea of the probability of the nature and violence of future disturbances at any one centre may be gained by consideration of the past records of the island concerned, the age and structure of its volcanoes and the oscillation-phase of the migration of disturbances along the volcanic arc (MacGregor).

f) Serious eruptions are most unlikely to take place without premonitory symptoms at the volcano in question. These symptoms have included (i) unusually numerous and increasingly violent local earthquakes for over a year before the initiation of explosions: Soufrière of St. Vincent 1902; (ii) increased gas-emission at soufrières, commencing at least two years before the eruption: Mt. Pelée 1902; (iii) change of soufrière gases from hydrogen sulphide to sulphur dioxide, beginning about a month before the initiation of explosions: Mt. Pelée 1929 (Anderson and Flett, Lacroix, Romer). There is thus no need to stress the desirability of *continuous* observation of seismo-volcanic phenomena.

g) While eruptions are taking place in one island of the Caribbean volcanic arc, earthquakes, earthquake series, increased gas-emission at soufrières, or even a simultaneous eruptive period may be initiated in another island (Fig. 2).

h) There is a general interconnection *throughout the whole Caribbean region* between volcanic activity, severe earthquakes and adjustments of crustal stability (ANDERSON and FLETT).

2) Other evidence used for purposes of prediction is as follows.

a) The foci of shallow local earthquakes in Montserrat in 1936 were distributed below parts of three of the seven old volcanoes of the island. If a local eruption had been imminent the epicentres would more probably have been confined to the area covered by the youngest volcano, the only one with active soufrières on its flanks (MACGREGOR).

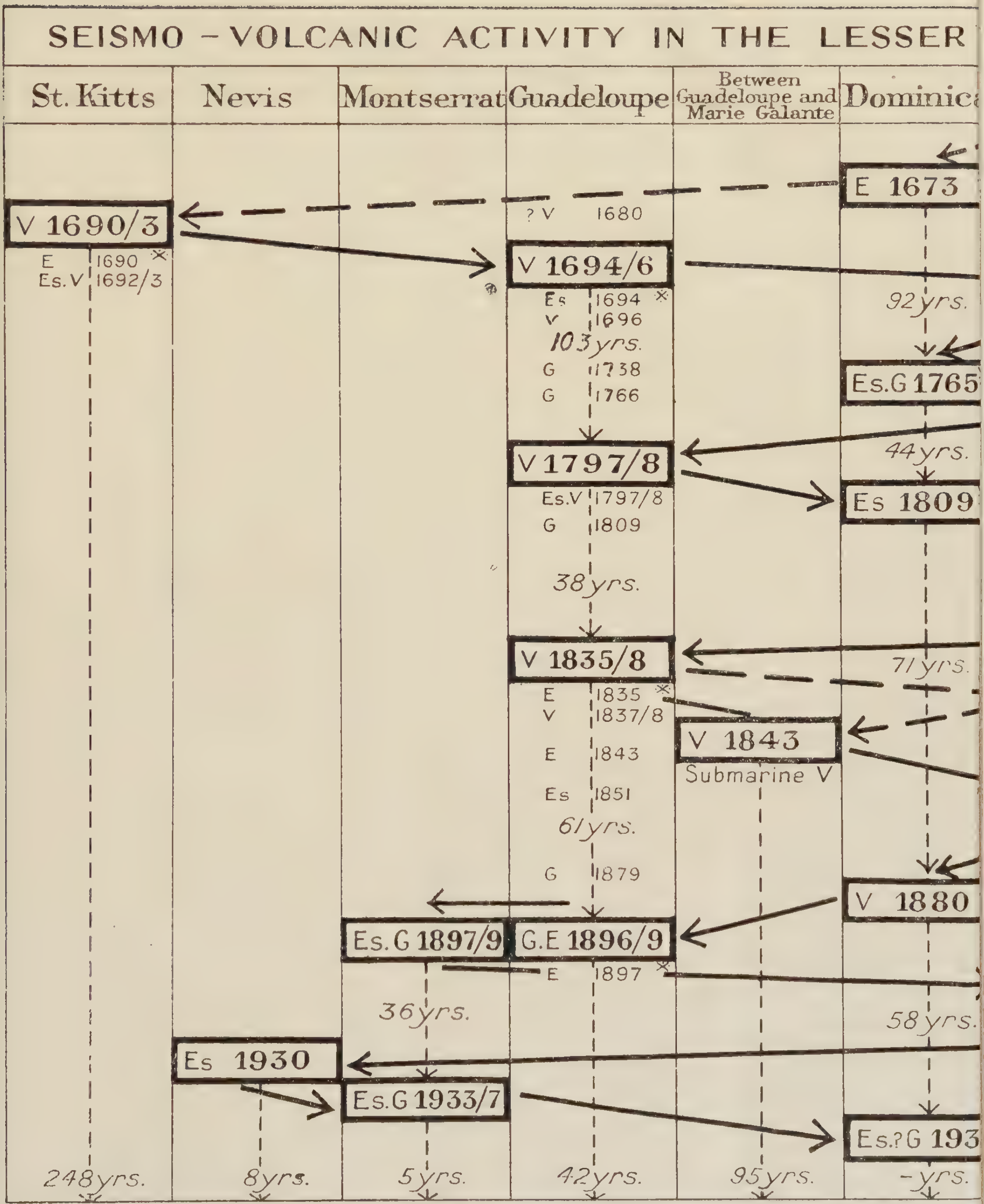
b) On Caribbean evidence of 1935/36 it is suggested that a major (world-wide) shock in a series of local volcanic earthquakes may be a sign that the peak of activity has passed (POWELL, MACGREGOR).

c) In Montserrat temporary intensifications of soufrière activity accompanied « seismic storms » of the earthquake series 1933/7. Abnormal gas-emission at soufrières usually preceded a shock of considerable violence; but a severe shock occurred without such a premonitory symptom; and increased gas-emission did not always herald shocks (PERRET).

d) In Montserrat (1933/7) gas-emission at soufrières remained normal in type (mainly hydrogen sulphide and steam; no acid gases such as sulphur dioxide) and temperatures remained close to the boiling point (of water) corresponding to local barometric pressure. It was inferred that a local eruption was unlikely (PERRET, POWELL, MACGREGOR; but see footnote p. 74.

e) Previous dome-building (accompanied by the production of *nuées ardentes*) was taken as an indication that the 1929/32 eruption of Mt. Pelée represented a late, decadent, stage in the evolution of this volcano. In general, dome-building represents a late, decadent, phase of all volcanoes of peléean affinities, characterised by somewhat acidic lava (PERRET). The validity of this inference in the Lesser Antilles is discussed, and upheld.

The occurrence of a peléean dome in the crater of a long

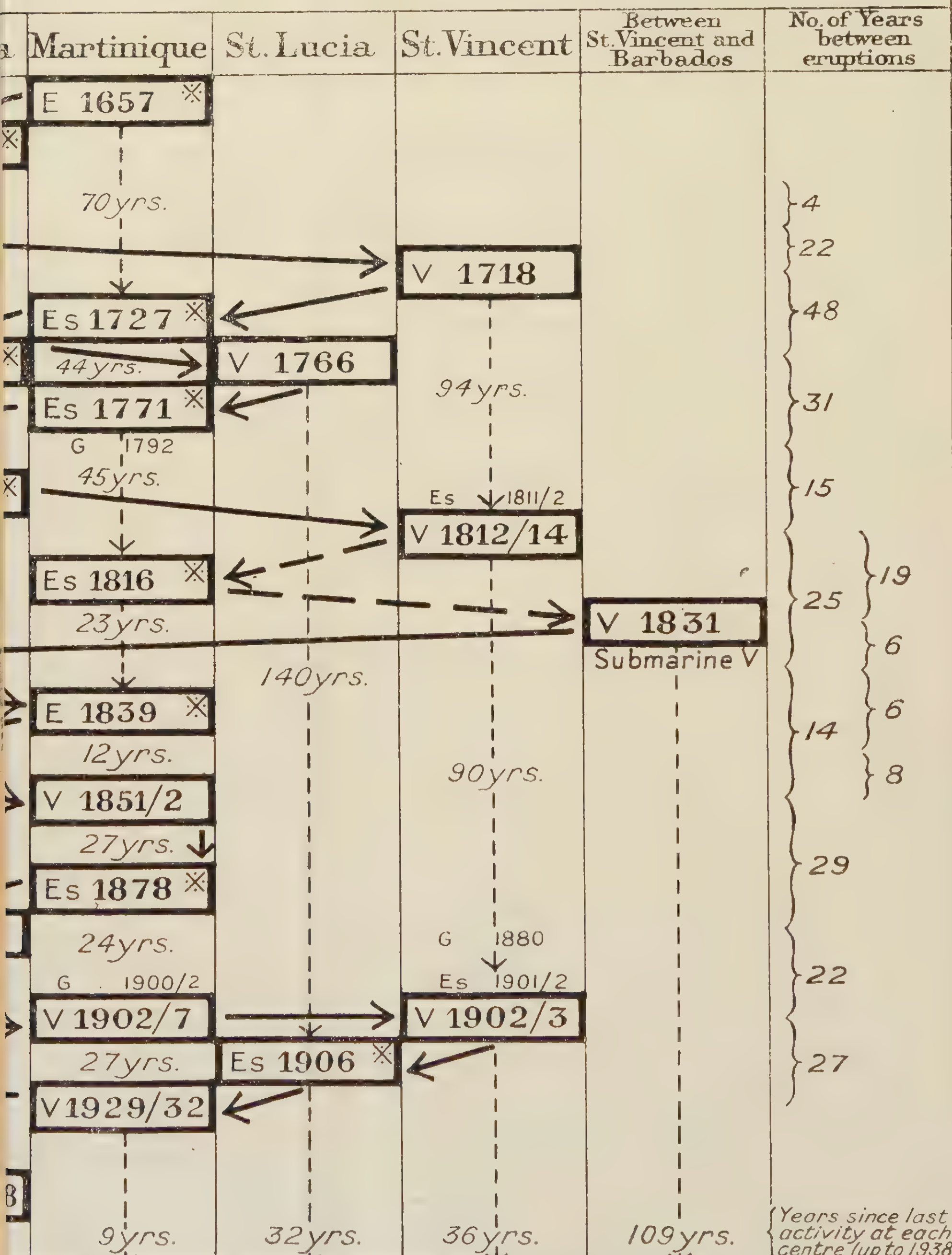


E = violent earthquake.
V = volcanic eruption

Es = earthquake series (*usually includes*
※ = Quoted from Perret (1939) only.
Oscillations involving seismic activity o

Fig. 2

ANTILLES WITHIN HISTORIC TIMES.



some violent shocks.) G = abnormal soufrière activity

)scillations of seismo-volcanic activity, shown by heavy arrows.

nly, shown by heavy broken arrows.

inactive volcano of peléean type in Montserrat was taken as evidence of volcanic decadence and of the improbability of a future violent eruption in the island (MacGregor).

f) The Soufrière volcano in St. Vincent resembles Mt. Pelée in many ways, but has no peléean dome in its crater. It is therefore suggested that dome-building (and, by implication accompanying eruptions of *nuée ardente* type) will probably take place in due course at this volcano, where eruptions have occurred at intervals of about ninety years since 1718 (Perret).

REFERENCES

Anderson, T. and J. S. Flett 1903. — *Report on the Eruptions of the Soufrière in St. Vincent, in 1902, and on a visit to Montagne Pelée in Martinique. Part I.* Philos. Trans. Roy. Soc. Lond., A, Vol. 200, pp. 353-553.

Anderson, T. 1908. — *Report on the Eruptions of the Soufrière in St. Vincent, in 1902, and on a visit to Montagne Pelée in Martinique. Part II.* Philos. Trans. Roy. Soc. Lond., A, vol. 208, pp. 275-302.

Lacroix, A. 1904. — *La Montagne Pelée et ses Éruptions.* Paris: Masson et Cie.

Lacroix, A. 1908. — *La Montagne Pelée après ses Éruptions.* Paris: Masson et Cie.

Lenox-Conyngham, Sir G. P. 1937. — *Montserrat and the West Indian Volcanoes.* Nature, Vol. 139, pp. 907-10.

MacGregor, A. G. 1938. — *Royal Society Expedition to Montserrat, B. W. I. The volcanic History and Petrology of Montserrat, with Observations on Mt. Pelée in Martinique.* Philos. Trans. Roy. Soc. Lond., B, Vol. 229, pp. 1-90.

MacGregor, A. G. 1946. — *Nuées ardentes and Ignimbrites.* Nature, Vol. 157, p. 305.

Perret, F. A. 1935. — *The Eruption of Mt. Pelée 1929-32.* Publ. Carneg. Inst., No. 458 (126 pp.).

Perret, F. A. 1938. — *Volcanic Conditions in Dominica.* The Dominica Tribune, 7 May 1938.

Perret, F. A. 1939. — *The Volcano-seismic Crisis at Montserrat 1933-1937.* Publ. Carneg. Inst., No. 512 (76 pp.).

Powell, C. F. 1937. — *The Royal Society Expedition to Montserrat B. W. I. Preliminary Report on Seismic Observations.* Proc. Roy. Soc. Lond., A, Vol. 158, pp. 479-94.

Powell, C. F. 1938. — *The Royal Society Expedition to Montserrat, B. W. I. Final Report.* Philos. Trans. Roy. Soc. Lond., A, Vol. 237, pp. 1-34.

ROMER, M. 1936. — *La dernière Éruption de la Montagne Pelée.* Bull. Volcanol., Vol. 8, pp. 89-116.

SAPPER, K. 1905. — *In den Vulkangebieten Mittelamerikas und Westindiens.* Stuttgart: Schweizerbart'sche Verlagsbuchhandlung.

SAPPER, K. 1927. — *Vulkankunde.* Stuttgart: Engelhorns Nachf.

WILLIAMS, H. 1932. — *The History and Character of Volcanic Domes.* Bull. Dep. Geol. Univ. Calif., Vol. 21, No. 5, pp. 51-146.

WOLFF von, F. 1929. — *Der Vulkanismus,* Bd. 2, Teil I, Stuttgart: Ferdinand Enke.

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The volcanoes of Kamchatka

(With 9 figures)

While the Pacific Ocean as a whole is fringed by mountain chains which are running parallel to the coast, its western part is framed by a series of mountain arcs convex towards the ocean and linked together in a « festoon » fashion (Fig. 1), Kamchatka, together with the Kurile Islands, form not only a link in this festoon of arcuate mountains and island arcs, but also a link in the « circle of fire » which girdles the Pacific Ocean.

The mountain arcs bordering eastern Asia in general may be considered to be made of folded strata uplifted during the Tertiary earth movements and accompanied by volcanic eruption of late Tertiary to Recent age.

The scientific study of Kamchatka's volcanoes began with the Russian expedition of 1737-1741 to Kamchatka. The scientific results of this expedition were presented in a brilliant work written by a very young Russian scientist, S. P. KRASHENINNIKOV (10). In spite of this effort Kamchatka for nearly another century remained a *terra incognita,* described only by two German explorers: ERDMANN (5) and DITMAR (3, 4). The first attempt to give a petrographical description of Kamchatka's volcanic rocks was made by JANKOVSKY (7) and this was followed by a more detailed study by BOGDANOVICH (1) who has spent over one year (1898-1899) exploring the volcanoes of Kamchatka. During the period of 1908-1911 KONRADY and KELL explored Kamchatka's volcanoes but the result of their work was published much later (9). The rsults of all this work were sum-

marised in the well known book by WOLFF (32) published in 1929. At a slightly later date KELL published the map of Kamchatka's volcanoes (8) and NOVOGRABLENOV a catalogue of Kamchatka's volcanoes (18).

A new impulse towards the study of Kamchatka's volcanoes was provided by the eruption of the Avacha volcano in 1926-1927. This eruption prompted the Geological Committee and the Academy of Science of the U.R.S.S. to organise a systematic study of Kamchatka's volcanoes, which was entrusted to A. N. ZAVARITSKY and resulted in the publication of three very important works dealing with Klyuchevskaya Sopka, Avacha and other volcanoes (33, 34, 35). In 1939, through the initiative of F. Y. LOEWINSON-LESSING, a volcanological station was established at the village of Klyuchi in the vicinity of Klyuchevskaya Sopka. After the death of LOEWINSON-LESSING in 1939, the station was directed by A. N. ZAVARITSKY who is also now in charge of a special Volcanological Laboratory in Moscow. The permanent and visiting staff of the Volcanological Station of Klyuchi is entrusted with systematic observation of volcanic activity, the study of lavas, ashes, gases, sublimates, thermal springs and geysers, the recording of seismic and meteorological phenomena and related events. The Volcanological Station consists of living quarters, chemical and petrographical laboratories and a library.

Kamchatka Volcanological Station has published since 1937 the « Bulletin of the Kamchatka Volcanological Station » both in Russian and in English.

* * *

The peninsula of Kamchatka, some 1300 km. in length, is a wild sparsely populated region. The Middle Range (Sredinny Khrebet) is studded with numerous extinct and dormant volcanoes. A broad valley occupied by Kamchatka River separates the Middle Range from the Eastern or Coastal Range along which all the active volcanoes of Kamchatka are situated. Some of the volcanic cones reach a considerable height and many support snow fields and glaciers.

The dominant factor in the geological structure of Kamchatka is the Tertiary folding which gave rise to a series of anticlines and synclines, recumbent folds and faults. In the cores of certain anticlines are exposed older rocks in age ranging from the pre-Cambrian to the Mesozoic and which include a variety of plutonic igneous rocks-granite, diorite, gabbro and peridotite. The Tertiary rocks comprise marine sediments, pyroclastics and lavas, ranging in age from Oligocene to Pliocene.

According to BOGDANOVICH (1) the volcanic activity in Kamchatka can be subdivided into four cycles:

I. Pliocene. Explosive and eruptive activity. Calderas, shield-volcanoes and cupolas. Mainly basic andesites.
II. Pliocene-Pleistocene. Acid andesites, dacites and liparites.
III. Pleistocene. Basalts, andesites.
IV. Recent. Volcanic activity (mainly explosive) restricted to the eastern belt. Basic andesites and basalts.

On the other hand PIIP (20) considers that volcanic activity in Kamchatka began in the Upper Mesozoic times and subdivided it into three major cycles:

I. Upper Mesozoic - Lower Tertiary. Augite - porphyries, Quartz-porphyries and diabase.
II. Miocene (?) - Pleistocene. Basalts, basic andesites, subordinate rhyolites.
III. Pleistocene - Recent. The volcanics of the eastern belt.

On the whole the lavas range from picrite-basalts and basalts to dacites and liparites with the predominance of andesite-basalts and andesites. This is clearly seen in the table of average analyses compiled by VLODAVETS (Table 1) and from the SiO_2 frequency curve (Fig. 8). No regular sequence of lavas, even in the case of a single volcano, has been definitely established as yet, although there are instances to be discussed later, where a regular sequence has been suggested. The discovery of pure dacitic volcanoes and recording of several flows of rhyolite suggests the possibility of the eruption of an intermediate - acid magma as an independent phase. This idea, however, finds no support in the general distribution of analyses nor in the SiO_2 frequency curve (Fig. 8).

The genetic or morphological classification of Kamchatka's volcanoes is rather difficult if well nigh impossible. Among the older eruptions flood basalts are common, while recent volcanoes belong to the central type characterised by an explosive activity, the type of Volcano, resulting in the building up of a composite or strato-volcano cone. Some of the rapidly formed volcanoes have a perfect cone, (e. g. Klyuchevskaya Sopka), others have greatly eroded cones (e. g. Koryaka or Viluchik). Pure lava volcanoes are rare, and among them fluid lavas such as basalt give rise to flat shaped cupolas, while viscous lavas, such as dacite, give rise to steeply inclined cupolas. Calderas are usually accompanied by pyroclastic materials. Basalt bombs are pear-shaped or twisted, while andesite bombs are usually of the bread-crust type. The lavas flows are usually of the block-lava type and pahoehoe lavas are scarce.

It is strange that in spite of the intensive survey of Kamchatka in recent times, the total number of volcanoes is still unknown and almost every year new extinct volcanoes are being discovered. According to ZAVARITSKY (35) the total number of volcanoes may be as high as 150 (counting separate cones and orifices) out of which some 20 are active or dormant.

Out of this number only 62 volcanoes are listed by ZAVARITSKY (37) and marked on his map (Fig. 2). On this map the solid or dotted lines indicate dislocation lines - faults or shatter belts. Two sets of such lines are present: 1) Principal set N - S or NNE - SSW; 2) Secondary set WNW - ESE. The first set agrees with the trend of the Kamchatka - Kurile arc, while the second agrees with the western prolongation of the Aleutian - Alaskan arc.

The transcription of the names of Kamchatka's volcanoes presents many difficulties. First of all a number of volcanoes have two names, one native Kamchadal and the other a Russian name; secondly the transcription of names written in Russian characters into Latin characters is often beset with difficulties and pitfalls; thirdly in Russian, names vary with the gender of the principal noun. So in Russian *SOPKA* (feminine gender) means a conical mountain, while *VULKAN* (masculine gender) means volcano. Thus the mountain situated near the village Klyuchi or Kluchi

or Kluchy, (this means springs, in this case - mineral springs) may be called either Klyuchevskaya Sopka or Klyuchevsky Vulkan.

The description of the individual volcanoes, which is to follow, is based mainly on the publications of A. N. ZAVARITSKY. In his review of Kamchatka's volcanoes (37) ZAVARITSKY gives a map of volcanoes (reproduced here as Fig. 2) on which the volcanoes are numbered: those belonging to the Eastern zone from 1 to 45, and those belonging to the Western zone from 46 to 62. Some of the volcanoes mentioned by name in the text are not given any numbers - these are probably smaller cones or parasitic cones. In the following list the numbers given by ZAVARITSKY are strictly adhered to. Each volcano whenever possible is provided with the following details 1) number, 2) name or names, 3) height in meters (in brackets), 4) state of activity (active, dormant or extinct), 5) recorded eruptions and character of eruptive activity, 6) morphological features, 7) nature of volcanic products. The numbers corresponding to active and dormant (fumarolic, sulfataric or mineral spring activity) volcanoes are in heavy type. Some of the volcanoes mentioned by ZAVARITSKY are not numbered.

I. — Eastern Zone.

The northernmost volcanoes in this zone are situated near the shore of Ozerny Bay. They have not been surveyed as yet and are unnamed. Little is known also about two extinct volcanoes Lezhiz and Urtochny situated to the north of Shiveluch, except that pyroxene-andesite has been found on them.

1. Shiveluch (3298 m.) Active. Recorded eruptions: 1790, 1854, 1897, 1928, 1945. Large monogenic volcano the southern part of which has subsided and the northern part forms the principal summit. It supports six independent glaciers. The lavas are andesitic. BOGDANOVICH (1) has described biotite - andesite as occurring among the lavas, but this is not confirmed by ZAVARITSKY, according to whom all the lavas are made of hornblende-andesite.

2. Kharchinsky volcano (1440 m.). Extinct strato-volcano composed of andesitic lavas and pyroclastics.

Zarechny volcano (Tuchov crater) (720 m.). Extinct. Ruined crater.

The volcanoes of Klyuchevsky group.

To the south of Kamchatka River and the village of Klyuchi is situated one of the most interesting groups of volcanoes (Nos. 3-9). BOGDANOVICH has suggested that the principal volcanoes of this group are disposed along a circular line which may be considered to represent a rim of a gigantic caldera. This is denied by ZAVARITSKY who thinks that these volcanoes are determined by a major tectonic line stretching NNE-SSW conjoined with a system of lines at right angles to it.

The volcanoes of this group are resting on a plateau some 1000 m. in height and made of ancient lavas and tuffs.

3. Klyuchevskaya Sopka, also called Kamchatsky Vulkan (4860 m.). Active. The first eruption was recorded in 1698 and since then over 20 major eruptions were registered. This number, however, must be considered to represent only phases of intensive activity for the volcano is in a state of perpetual activity. This activity is mainly of explosive type, only after long intervals becoming eruptive. The cone is perfect and its upper part is composed of pyroclastic materials and ice (Fig. 3). One may even consider the whole upper part of the cone as a huge firn-glacier made of ashes and ice. This cone-shaped glacier terminates in a series of sharp tongue-glaciers situated at a height of 1200 m. Ashy ice is often interbedded with lava flows. Newly erupted lavas are usually rapidly covered up by ashes and lapilli which get mixed up with snow and form ashy-firn-ice. Along the lower slopes of the cone and at its foot are situated numerous parasitic cones. According to VLODAVETS these cones are roughly grouped along radial and concentric lines. The flows consist of block-lava of basalt and andesite basalt.

During the last two great periods of intensive activity (August-October 1935 and April 1937 to March 1939) the total

volume of lavas and ashes erupted amounted to 437 million cubic meters. A rough calculation shows that the volume of the present cone represents the product of 700 eruptions of intensity equal to the last two eruptions. This provides an estimate of the age of the volcano of 5000 years.

These two eruptions provided material for the study of lavas erupted at different levels of the volcanic cone, which were as follows:

Height	Rocks	SiO_2%
4 800 m.	Andesite-basalt	54.5
1 800 m.	Andesite-basalt	53.9
900 m.	Basalt	51.5

This suggests a possibility of a gravitational differentiation inside the volcanic pipe and in this respect it may be analogous to the case discussed by MACDONALD (12).

In 1938 a parasitic cinder cone named Bilukay was formed on the eastern slope of Klyuchevskaya Sopka. In six weeks time this cone reached the height of 110 meters. It emitted a lava flow six kilometers long followed by another somewhat smaller in length. These lava flows were studied by V. F. POPKOV and I. Z. IVANOV (23) who achieved a remarkable feat of drifting for a distance of two kilometers, on a raft of solid lava along the incandescent lava flow. During their drift they studied the temperature of lava and sampled the gases. The velocity of the lava as measured was 44 metres per minute near the crater and was lower below. The temperature of the liquid lava varied between 870° and 690° C, while the temperature of the raft varied between 300° and 270° C.

The volume of gases discharged from the lava was very high. According to POPKOV, 196 million cubic metres of gases (mainly steam) were emitted by Klyuchevskaya Sopka during the intensive phase of its activity in 1938-1939. The parasitic crater of Bilukay was emitting 1,200,000 cubic metres per hour.

Klyuchevskaya Sopka erupted again in December 1944, January 1945, and October 1946.

4. Kamen (« stone ») (4650 m.). Immediately south of Klyu-

chevskaya Sopka. Extinct strato-volcano. The eastern part of the cone is crossed by a fault and destroyed by glaciers.

5. Besymyannaya Sopka (« Nameless Sopka ») (3150 m.). Immediately south of Kamen. Large denuded volcano with remains of lava flows of pyroxene-andesite.

6. Zimina Sopka. According to VLODAVETS this volcano is formed by the confluence of three separate volcanoes. Mainly composed of andesite lavas including a singular type of sanidine-andesite.

Plotina (« dam »). A dome-shaped mass of hornblende-andesite. Situated between Besymyannaya Sopka, Zimina Sopka and Tolbachik.

7. Tolbachik. Made of two confluent cones, of which the western (3730 m.) is extinct, while the eastern (2860 m.) is a flat-dome-shaped active volcano. The lavas are very abundant and cover an extensive area, one of the flows forming a large « lava-lake ». The pyroclastic materials are scarce. The slopes of the volcano are studded with parasitic cones. The main crater is some 1350 metres in diameter and 150 metres in depth. It is partly filled with ice and rock debris through which volcanic gases are constantly escaping. The lavas are mostly basaltic in composition.

The first recorded eruption is that of 1739 and the last of 1939-1941. During the last eruption the crater became infilled with liquid lava through which the gases bubbled through often with an explosive violence. On the 7th May, 1941, an explosion occurred on the southern slope of the main cone. This resulted in the formation of a parasitic cone and in the emission of a block-lava flow of olivine-basalt 5 km. in length.

8. Major (2060) and Minor (2000) Udina Sopka. Two extinct cones carved by barrancos. The lavas are andesitic.

9. Ploskaya Sopka (« Flat Sopka ») (4030 m.). Probably a lava cone made by andesite-basalts and andesites, but greatly obscured by glaciers.

Srednya Sopka (« Middle Sopka »). A small volcanic cone between Klyuchevskaya Sopka and Ploskaya Sopka.

10. Kizimen or Shchapinskaya Sopka (2800 m.). Active volcano. Regular cone carved by barrancos and capped by ice.

11. Kunchokla. A ruin of a large volcano.

12. Shish («knob») (2430 m.). A small rocky volcano astride a folded mountain chain. Andesitic lavas and ashes.

To the south-west of Shish are situated several small little-known volcanoes.

13. Tymrok. A large ring-shaped denuded volcano.

14. Konrady Sopka (2000 m.). A denuded double-cone volcano.

15. Gamchen (2600 m.). A large cone.

16. Schmidt Sopka (1900 m.). A denuded volcano.

17. Kronozky Volcano (3730 m.). Active volcano. Regular cone.

18. Krasheninnikov Volcano (1821 m.). A well preserved extinct volcano of Somma-Vesuvius type.

19. Kikhpinych (1740 m.). Fumarolic activity.

20. Unana (2020 m.). Caldera with intrusive domes and spines. Hot springs.

21. Taunshiz (2250 m.). Two confluent cones. Pyroxene-andesite lavas.

22. Uzon (1540 m.). Caldera some 10 km. in diameter, the western part of which is composed of interbedded basalt lavas

and tuffs and is cut by dolerite and basalt dykes, while the western part is composed of glassy rhyolites. The interior of the caldera contains large accumulations of rhyolitic pumice. According to PIIP the history of this volcano is as follows:

Along the eastern margin of the original strato-volcano composed of basalt, basaltic agglomerate and tuff, occurred an intrusion of acid magma which was followed by a tremendous explosion which destroyed the original cone and formed a caldera, at first infilled by lava, but later shattered by a second explosion which gave rise to a deep round crater-lake surrounded by andesite-basalt scoria. At the present time the caldera contains numerous fumarola, mud volcanoes and hot springs.

23. Bolshoy Semyachik (1720 m.). Large caldera occupied by a glacier. Last important eruption occurred in 1852. At the present time in a fumarolic and solfataric stage of activity.

24. Maly Semyachik. A small extinct volcano.

25. Karymskaya Sopka or Berezovaya Sopka (1400 m.). One of the most active volcanoes of Kamchatka, but as yet little studied. During the last 25 years this volcano erupted seven or eight times. In 1938 it was visited by VLODAVETS who discovered dacitic and rhyolitic lavas at the foot of the cone which was made of volcanic ash. In the vicinity VLODAVETS discovered eight new extinct volcanoes and several groups of hot springs.

26. Razvalenny Volcano (1680 m.). A partly denuded volcano composed by andesites and dacitic and rhyolitic tuffs.

Ditmar Volcano. A newly discovered volcano which has an intrusive mass on its northern slope.

27. Zhupanova Sopka (2931 m.). Three confluent cones, the western cone being active. The cones are composed of alternate andesitic lavas and volcanic agglomerate. Fumarolic activity is present and in places the lavas are kaolinized and impregnated by gypsum and sulphur.

28. Yurievsky Volcano (1200 m.). A greatly denuded extinct volcano.

28 *a*. Dzenzursky Volcano (2200 m.). A greatly denuded extinct andesitic volcano.

28 *b*. Zavaritsky Volcano (1600 m.). Discovered and named by Piip but little studied.

28 *c*. Scoria cone of Zhupanov Col.

28 *d*. Pravaya Sopka (1800 m.). No information.

28 *e*. Arik (1800 m.). Greatly denuded cone with andesitic lavas.

28 *f*. Aak (1500 m.). Caldera containing a glacier.

This region, however, has been but little studied and more volcanoes may be discovered in future, especially along the Ivulk Ridge where a number of rhyolitic and andesitic domes have been recorded.

29. Avacha (2725 m.). This active volcano is situated near Petropavlovsk, the principal town in Kamchatka, and it may be considered to be the best studied volcano in this country. It is of Somma-Vesuvius type. (Figs. 4 & 5). The active crater is placed excentrically within the partly destroyed ancient caldera. The diameter of the caldera is about four kilometres and its height 2300 metres. The space between the cone and the caldera is partly occupied by glaciers. Cut by deep barrancos the slopes of the « Somma » stand in strong contrast to the perfect cone made of flows of block-lava. The early eruptions consisted of basaltic and andesitic lavas intercalated with tuffs.

During the 18th and 19th century Avacha erupted some 22 times. During the present century Avacha erupted in 1909, 1910, 1926, 1927 and 1937-1938. In 1931 a special expedition was organised for the study of this volcano, the results of which were published by Zavaritsky (34). The eruption of 1937-

1938 was studied in detail by MENIAILOV and other workers (13, 14, 15, 20, 21, 22, 25). This eruption was preceded by an intense fumarolic activity. In October 1937 the first explosion of gases took place. In January 1938 lava filled in the crater and there was an intensification of explosive activity. In March mud and agglomerate flows began to be erupted and paroxysmal eruptions and explosions continued to the end of 1938. No liquid lava flows were erupted, but only incandescent mud and agglomerate flows comparable with *nuées ardentes*.

The amount of water contained in these flows must have been very considerable and part of it, no doubt, was derived from snow and ice decking the volcano.

30. Kozelskaya Sopka. An extinct volcanic cone situated immediately south of Avacha.

31. Koryaka (3460 m.). Fumarolic stage of activity. A regular cone situated to the N. W. of Avacha. The last recorded eruption occurred in 1896. The lavas are andesitic.

Koryaka, Avacha and Kozelskaya Sopka are probably situated along one fissure.

32. Scoria cones probably representing a series of small volcanoes situated along a line of fissure parallel to the River Eastern Avacha.

33. Bakenin, or Bakang, or Kamchatka Peak (2300 m.). Traces of recent volcanic activity: fresh lava flows, dry stony valleys, parasitic craters. The volcano is in the form of a regular cone placed in a caldera. The lavas are andesites and olivine basalts.

34. Viluchik or Viluchinskaya Sopka (2175 m.). A regular cone situated S. W. of Petropavlovsk. Lavas of andesite-basalt containing numerous phenocrysts of plagioclase and olivine rimmed by hypersthene as well as xenoliths of hornblende-hypersthene-andesite. Dacite lavas occur at the base of the volcano and to the north of the volcano are found rhyolite domes and basaltic scoria cones.

35. Mutnovskaya Sopka (2320 m.). The volcano is in a state of constant gaseous activity. It consists of a caldera 3 km. in diameter filled in by a glacier which contains clear ice interbedded with pyroclastic materials. An ice-fall within the caldera is covered by volcanic sand and blocks of lava. The lavas are basaltic, andesitic and dacitic. A large proportion of them is highly decomposed and impregnated with sulphur and gypsum.

36. Gorely Khrebet (« Burned Ridge ») (1830 m.). Active volcano with paroxysmal eruptions. First recorded eruption in 1821, last recorded eruption in 1932. Large caldera partly obliterated by numerous lava flows and containing inside five small craters. The lavas are augite-andesites.

37. Opala (2470). Volcanic activity recorded in the 18th century. A regular cone inside a large caldera. Lavas: olivine-augite-andesite, andesite-basalt, two-pyroxene andesite, hyalo-dacite, hyalo-rhyolite.

Between Opala, Gorely Khrebet and Asacha are situated numerous small volcanoes, which have not been studied as yet.

38. Asacha (1900 m.). A large greatly denuded extinct volcano. Lavas consist of two-pyroxene andesite.

39. Khodutka or Golygina (2070 m.). Hot springs activity. A regular cone excentrically placed within a caldera 7 km. in diameter. Lavas: augite-hypersthene-andesite.

40. Predpolagaemaya Vershina (« Supposed Height ») (705 m.). Probably a dacitic « extrusive » plug.

41. Ksudach or Stübel Volcano. In 1910 Konrady and Kell named this volcano in honour of A. Stübel in ignorance of the local Kamchadal name Ksudach. Piip (19) later suggested that the name Stübel volcano should only be applied to the active cone which was found inside a caldera 7 km. in diameter in 1907. The cone is composed of andesitic pyroclastics while the caldera is composed mainly of basaltic lavas.

Sakhach or Belenkaya (885 m.). An extinct volcano adjoining Ksudach. Composed of basalt lavas and agglomerate.

42. Zheltovskaya Sopka (1950 m.). An active volcano the last eruption of which occurred in 1923. Vesuvius-Somma type made of andesites and pyroclastics.

43. Ilyinskaya Sopka (1570 m.). In a state of fumarolic and hot-springs activity. A typical strato-volcano made of andesites and pyroclastics.

Diky Khrebet (« Wild Ridge ») or Karakuli. A high volcano of a pyramidal shape made of lavas and ashes.

44. Kambalnaya Sopka (2140 m.). A half-destroyed cone with the crater occupied by a glacier.

45. Kosheleva Sopka or Chaokhch (1900 m.). In a fumarolic stage of activity. A cone with a caldera. Lava flows of basaltic and andesitic composition.

II. — Western Zone.

These volcanoes are much less known than those of the eastern zone. Only one of them (No. 57 Khoashen) is reported as active. Many are unnumbered.

46. Kikhiikhylkhangey.
Kulina.
Aulpal (1200 m.).

47. Anangravnen (1700 m.). A large truncated cone with andesitic lavas and pyroclastics.
Baidara. Basaltic.

48. Massa. Andesitic.
Tylele.
Melpe.

49. Aligey.

50. Ainelkan (2000 m.). Caldera like depression with lavas of andesite and andesite-basalt.

51. Shishel or Sisel. Remnant of a caldera open to the east.

52. Leitungey. A slag cone placed on the margin of a gigantic caldera.

53. Krasnaya Sopka (« Red Sopka ») (950 m.). Denuded cone made of andesites.
Minchventen (1000 m.).
Slunin Volcano.
Margaritov Volcano (1200 m.).
Erdmann Volcano.

54. Kruglaya Sopka (« Round Sopka »).

55. Bely (« White »). A volcanic ridge 1650 m. in height covered by snow and glaciers. Andesitic and dacitic lavas.

56. Anaun (1860 m.). Cone and caldera with andesite-basalt lavas.

57. Khoashen or Ichinsky Volcano (3500 m. ?). Three craters emitting vapours. A large volcanic cone covered by glaciers. Lavas of hornblende-augite-andesites and glassy acid lavas.

57 *a*. Loewinson - Lessing Volcano. So named by D. C. KHARKEVICH. Probably a destroyed shield-volcano composed by andesites and andesite-basalts.

58. Khangar (2100 m.). Ruins of a large volcanic cone composed of trachyte-andesites, dacites and rhyolites.

59. Shapochka. Flat cone made of basalts and andesites.

60. Eluelik (220 m.). A dome or laccolite made of trachyte and andesine-porphyry.

61. Ipelka. Remains of a large volcano having the form of a ring-shaped ridge made of augite-andesite.

Kichua. « Ipelka in miniature ». A denuded volcano situated to the south of Ipelka.

62. Yavinsky Volcano. A small slag cone with a lava flow of olivine-basalt.

This completes the list of volcanoes as known at the present time.

A large amount of work has been also done in the study of volcanic gases and sublimates, especially those of Klyuchevskaya Sopka. According to NABOKO (17) the volcanic gases consist mainly of steam with varying amounts of hydrochloric and hydrofluoric acids, sulphur dioxide, carbon monoxide and carbon dioxide, methane, ammonia, hydrogen, oxygen and nitrogen. NABOKO subdivides the fumaroles into two main groups, chloridic and sulphatic, and the first group into 1) hydrous (800°C) producing no sublimates, 2) halitic (500°C), 3) mixed (500°-800°C), 4) ammoniac (300°C) and 5) fluoritic (below 200°C). Among the volcanic sublimates forty-six chemical elements have been recorded. There are on Kamchatka 68 groups of thermal springs and seventeen large geysers, the study of which has only recently begun.

Kamchatka is situated on the circum-Pacific seismic belt and is affected both by volcanic earthquakes and tectonic earthquakes. GORŠKOV and POPOV (6) have noted the coincidence of the epicentral zones of Kamchatka with the positions of the active volcanoes (Fig. 6). According to VLODAVETS (28) the epicentres are arranged along two sets of lines 1) NNE - SSW and 2) W - E (Fig. 7). These lines are parallel to the tectonic lines of the Kamchatka-Kurile arc and Alaskan-Aleutian arc respectively, and also coincide with the lines of alignment of volcanoes (Fig. 2).

* * *

The garland of the Kurile Islands represents the submerged part of the Kamchatka-Kurile volcanic arc. MILNE (16), who was the first to describe Kurile Volcanoes in 1879, noted their perfect shape and their recent appearance. According to him there are 50 volcanic peaks and of these nine are active. According to ZAVARITSKY (41) there are 38 volcanoes of which 14 are active, while according to SOLOVIEV (24) there are 52 volcanoes out of which 18 are active. Taking the latest figures as being correct we have for the whole Kamchatka-Kurile volcanic arc some 200 volcanoes out of which 38 are active. These volcanoes are dispersed along a belt some 2300 km. long. The adjoining Alaskan-Aleutian arc is some 2100 km. long and, according to WOLFF (32, p. 586), contains 61 volcanoes of which 33 are active.

MILNE, from a few specimens of lavas collected concluded that the lavas of Kurile Islands are augite-andesites. This was later generally confirmed by Japanese geologists, but KUNO (11) has also discovered on Alaid and Taketomi volcanoes olivine-basalts and elsewhere dacite. For the whole Kurile group of islands KUNO gives only six chemical analyses: four of basalt, one of andesite and one of dacite. These analyses fall nicely among the Kamchatka basalt-andesite-rhyolite series.

The volcanic rocks of Kamchatka belong to a definite subalkalic suite and within this suite there is a continuous gradation ranging from olivine-basalt through andesite-basalt, andesite, andesite-dacite, liparite-dacite to liparite. The continuous nature of this variation can be seen on any variation diagram, such as that of alkali-silica diagram (Fig. 8) while the average for each type are presented on Table 1. VLODAVETS has assembled 164 analyses of Kamchatka volcanic rocks (27,30) a collection which provides a rich material for petrochemical deductions. The best approach to this problem is through a study of variation diagrams and for our purpose the best diagram is that of alkali-silica variation. Lime-silica variation diagram is as a rule reciprocal of alkali-silica diagram and other oxides are less sign-

ificant. The variation should be studied if possible in two forms, first a scatter diagram of individual points (Fig. 8) and then as a diagram of averages through which the variation curves can be traced (Fig. 9). The actual tracing of variation curves should, if possible, be guided by the scatter point diagrams for aberrant analyses can, in certain cases, deflect the direction of curves. The alkali-silica variation curves when produced for several provinces or periods provide an excellent guide of petrochemical deductions.

In Fig. 8 the upper diagram gives the frequency curve for SiO_2. This curve shows a mode at 55% SiO_2 which agrees with the weighted average (Table 1) calculated on the basis of relative volumes of rocks. This average roughly corresponds to andesite-basalt in composition. The lower diagram represents the scatter diagram for alkali-silica variation. The points form a well defined belt some 4 per cent wide and a range from 45 to 75 per cent SiO_2. The continuous nature of the variation and the mode situated at the andesite-basalt, suggest that the parent magma corresponds to andesite-basalt and that the other rocks both basic and acid are products of its differentiation. This, however, is only one of the possible ways of interpreting the petrochemical evidence. A line of best fit drawn through the individual point is represented on Fig. 9 where the value of averages for rock groups are represented by solid dots. The rocks of Alaskan-Aleutian volcanoes, as one can see from the diagram (Fig. 9) fall well with those of Kamchatka. The averages for the volcanic rocks of Alaskan-Aleutian arc were obtained from 26 individual analyses (Table 2) but the first analysis (SiO_2 49,30), being aberrant, as exceptionally rich in H_2O, has not been included. The volcanic rocks of Japan. as averaged from 136 individual analyses by YAMADA (Table 3) form a series running parallel to the Kamchatka series but on the average one per cent lower. This means that the volcanic rocks of the Japanese arc are slightly less alkaline than those of Kamchatka. This fact is rather significant for we are here not judging individual analyses but an assemblage of a comparatively large number of analyses. It is also significant because the rocks of the Alaskan-Aleutian arc agree with those of Kamchatka.

The only explanation of this fact, as far as I can imagine, lies outside the volcanic arcs as such. It is a well known fact that all the arcs belonging to the Circum-Pacific belt are characterised by sub-alkalic series, in contrast to the rocks of the Central Pacific region which is characterised by alkaline rocks. This scheme, however, does not exhaust the real state of things. It is a less known fact that in the hinterland of many Circum-Pacific arcs we have a development of igneous rocks with marked alkaline tendency or even strongly alkaline. Such is the case of the Australian Kainozoic igneous rocks which are found in the hinterland of the New Guinea - NewZealand arc, the rocks of the inner side of the Java-Sumatra arc (the northern shore of Java, and some other localities).

In the case of the Alaskan-Aleutian arc we see alkaline rocks occurring on the islands of the Bogoslov and Pribilof groups (31). Unfortunately only three analyses of these rocks have been published but these show quite clearly the alkaline nature of these rocks (Fig. 9). The igneous rocks from the inside of the Kamchatka-Kurile arc are little known. The Isle of Sakhalin, for example, besides volcanoes belonging to the Sakhalin - Japan arc, contains a number of late intrusive rocks such as essexite and tephrites, described by DERWIES (2). In northern Manchuria, near Mergen, ZAVARITSKY (40) has described strongly alkaline potash-rich lavas from recent volcanoes. There is other information suggesting that alkaline rocks are found in other districts of the Kamchatka-Kurile hinterland. Both in the case of Alaskan-Aleutian and Kamchatka-Kurile arcs, the alkaline rocks of the hinterland are relatively poorly developed. Such is not the case of the hinterland of the Sakhalin - Japan arc. The region immediately to the west of the Japanese sector of the arc, namely the western shore of southern Japan, the isles on the Sea of Japan, Korea, Eastern China and Mongolia, form part of an extensive « East Asiatic alkaline province ». TOMITA (26) has described the igneous rocks of the western part of this province, a part named by him « Circum-Japan Sea Region », a somewhat misleading term, since in this case he does not mean the region of the Circum-Japan Sea, as such does not exist, but the region surrounding the Sea of Japan. The rocks

of this region, as Table 4 and Fig. 9 show, are strongly alkaline and stand in a strong contrast to the strongly sub-alkaline rocks of the Japanese arc (Table 3, Fig. 9). The existence of such extensive alkaline province inside the Japanese arc may perhaps provide an explanation of the lowering of alkalinity in the rocks of the Japan arc. While in the case of the Alaskan-Aleutian and Kamchatka-Kurile arcs, the amount of alkaline magma produced and erupted in the hinterland was negligible, in the case of Japan the development of such a magma was very considerable. Postulating a parent magma of a composition of the average andesite-basalt such as prevalent in Kamchatka, one may suggest that in the case of Japan the differentiation into strongly alkaline and strongly sub-alkaline fractions went very far and this resulted in the rising of the curve for alkaline group and corresponding lowering of the curve for the sub-alkaline group.

If these considerations can be applied to the rocks of the whole of the Pacific Ocean, one could postulate the Circum-Pacific arcs as having igneous rocks of predominantly sub-alkaline character, while both of the foreland (Central Pacific area) and of the hinterland (the areas inside and behind the arcs) having igneous rocks representing the alkaline differentiation pole of the primary andesite-basalt magma.

This idea, however, represents a pure hypothesis and until the whole Pacific Ocean igneous region are studied in greater detail, one would be rash to draw any conclusions. It may be that the idea of HARKER that the origin of magma types is linked up with the types of tectonic movement will be vindicated and that the sub-alkaline magma type is associated with the tangential movements leading to the formation of folded arcuate mountains, while the alkaline magma-type is associated with the vertical movement, leading to the foundering of the earth's crust.

TABLE 1.

Averages of chemical analyses of volcanic rocks of Kamchatka. (VLODAVETS, 1939, 1946).

	Picrite-basalt	Basalt	Andesite-basalt	Andesite	Andesite-dacite	Dacite	Liparite-dacite	Liparite	Total average	Weighted average
Number of Analyses	3	59	37	19	16	15	4	11	164	
SiO_2	45.54	51.47	55.37	58.68	61.64	66.17	69.31	72.41	57.18	55.47
TiO_2	0.75	0.87	0.96	0.83	0.48	0.47	0.38	0.28	0.78	0.84
Al_2O_2	18.37	17.91	17.64	16.93	16.84	16.05	14.46	13.15	17.07	17.73
Fe_2O_3	7.69	4.44	3.77	3.03	3.93	3.09	2.47	2.54	3.83	4.08
FeO	4.46	5.01	4.57	4.15	2.31	1.34	1.31	0.78	3.87	4.50
MnO	0.12	0.13	0.13	0.12	0.11	0.08	0.03	0.06	0.12	0.13
MgO	6.27	5.74	3.96	3.20	2.32	1.33	0.71	0.56	3.84	3.31
CaO	10.61	9.12	7.72	6.30	5.23	3.62	2.45	1.98	6.99	7.95
Na_2O	2.70	2.64	3.04	3.34	3.66	3.83	4.47	3.69	3.14	3.00
K_2O	1.17	1.03	1.24	1.73	1.75	2.48	2.78	3.07	1.55	1.33
P_2O_5	—	0.22	0.26	0.24	0.21	0.17	—	0.06	0.21	0.22
H_2O	2.32	1.42	1.34	1.45	1.52	1.37	1.63	1.42	1.42	1.44
Alkalies	3.87	3.67	4.28	5.01	5.41	6.31	7.25	6.76	4.69	4.33

TABLE 2.

Averages of chemical analyses of volcanic rocks of the Alaskan-Aleutian arc (WOLFF, 1929).

	I	II	III	IV	V
Number of analyses	1	6	8	8	3
SiO_2	49.30	54.25	59.61	64.49	72.40
TiO_2	0.84	0.82	0.75	0.64	0.29
Al_2O_2	17.30	17.70	16.50	15.96	13.86
Fe_2O_3	5.22	4.15	2.50	2.38	1.08
FeO	3.71	3.63	3.94	2.38	1.26
MnO	0.18	0.15	0.12	0.10	0.07
MgO	6.32	4.02	3.57	2.19	0.50
CaO	8.19	8.10	6.66	4.98	2.42
Na_2O	2.32	3.33	3.71	3.95	4.17
K_2O	0.16	1.05	1.28	1.84	2.67
P_2O_5	0.14	0.28	0.24	0.22	0.20
H_2O	6.32	2.52	1.12	0.37	1.08
Alkalies	2.48	4.38	4.99	5.79	6.84

TABLE 3.

Avereges of chemical analyses of volcanic rocks of Japan (TOMITA, 1935).

	Basalt	Andesite-basalt	Andesite	Rhyolite-andesite	Rhyolite
Number of analyses	7	22	57	40	10
SiO_2	47.3	51.9	59.6	64.6	73.5
TiO_2	0.2	0.5	0.2	0.3	0.1
Al_2O_2	18.5	18.2	17.5	16.3	13.9
Fe_2O_3	6.6	3.9	3.7	2.6	1.4
FeO	5.5	7.0	3.8	3.1	1.0
MnO	0.1	0.1	0.1	0.1	0.1
MgO	5.3	4.5	2.7	1.6	0.5
CaO	12.2	9.8	6.9	5.3	1.6
Na_2O	1.8	2.2	2.7	2.9	3.0
K_2O	0.4	0.6	1.4	1.7	3.2
P_2O_5	0.1	0.1	0.2	0.2	0.2
H_2O	2.0	1.2	1.2	1.3	1.5
Alkalies	2.2	2.8	4.1	4.6	6.2

TABLE 4.

Averages of chemical analyses of igneous rocks of the alkaline Trans-Japanese province. (TOMITA, 1935).

	Limburgite - basanitoid	Basalt-trachybasalt	Trachyandesite basalt	Trachyandesite	Trachyte	Trachyliparite	Comendite
Number of analyses	12	27	14	11	16	16	21
SiO_2	41.97	47.77	52.35	57.51	62.63	66.97	72.71
TiO_2	2.10	2.19	1.71	1.11	.55	.43	:28
Al_2O_2	14.94	16.41	17.67	18.79	17.25	14.93	12.14
Fe_2O_3	4.73	3.29	3.17	2.63	2.13	1.55	2.12
FeO	7.56	7.20	5.75	3.18	2.34	2.44	2.25
MnO	.48	.20	.18	.15	.21	.15	.09
MgO	8.43	5.94	3.16	1.38	.40	.27	.16
CaO	11.34	9.34	7.61	4.0	2.21	1.28	,62
Na_2O	3.02	3.44	4.24	5.02	5.34	5.30	4.26
K_2O	1.50	2.08	2.54	4.65	5.19	5.47	4.49
P_2O_5	1.10	.69	.48	.40	.20	.09	.04
H_2O	2.83	1.45	1.14	1.18	1.55	1.12	.84
Alkalies	4.52	5.52	6.78	9.67	10.53	10.77	8.75

References

1. Bogdanowitsch, K. — *Geologische Skizze von Kamtschatka.* Peterm. Geogr. Mitt., 1904, vol. 50, pp. 59, 96, 122, 144, 170, 196, 217.
2. Derwies, V. von — *Roches cristallines de la partie nord de l'île de Sakhaline.* Mém. Com. Géol. Petrograd, 1915, N. S., No. 102.
3. Ditmar, C. von — *Die Vulkane und heissen Quellen Kamtschatkas.* Peterm. Geogr. Mitt., 1860, p. 66.
4. ——— — *Reisen und Aufenthalt in Kamtschatka, in den Jahren 1851-1855.* In Beiträgen zur Kenntniss des Russischen Reiches und angrenzenden Länder. St. Petersburg, 1890, 1900.
5. Erdmann, Ad. — *Reise um die Erde durch Nordasien und die beiden Ozeane.* Band III. Berlin, 1848.
6. Gorškov, G. P. and Popov, V. V. — *A short review of the seismicity of the Kamchatka peninsula.* Bull. Kamchatka Volcan. Station, 1938. No. 4, p. 23.
7. Jankowsky, W. — *Beitrag zur Petrographie von Kamtschatka und der Bai des Heiligen Kreuzes.* Trav. Soc. Nat. St. Petersbourg. Sect. Géol. Min., St. Petersbourg, 1895, vol. 23, p. 61.
8. Kell, N. G. — *The map of Kamchatka's volcanoes.* Bull. Russian Geogr. Soc., 1932.
9. Konrady, S. A. — *Report on Kamchatka 2 March 1911.* Bull. Russian Geogr. Soc., 1925, vol. 57.
10. Krasheninnikov, S. P. — *The description of the land of Kamchatka.* St. Petersburg, 1755, 2 vols.
11. Kuno, H. — *Petrology of Alaid volcano, North Kurile.* Japanese Journ. Geol. & Geogr., 1935, vol. 12, p. 153.
12. Macdonald, G. A. — *The 1840 eruption and crystal differentiation in the Kilauean magma column.* Amer. Journ. Sci, 1944, vol. 242, p. 177.
13. Meniailov, A. A. — *The eruption of Avacha in 1938.* Bull. Kamchatka Volcan, Station, 1939, No. 6, p. 21.
14. Meniailov, A. A. and Sosunov, N. F. — *The activity of the Avachinski and Mutnovski volcanoes (April-September 1938).* Bull. Kamchatka Volcan. Station, 1939, No. 8, p. 21.
15. Meniailov, A. A. and Sosunov, N. F. — *The activity of the Avachinski and Mutnovski volcanoes from October 1 to December 31, 1938.* Bull. Kamchatka Volcan. Station, 1940, No. 8, p. 43.
16. Milne, J. — *A cruise among the volcanoes of the Kurile Islands.* Geol. Mag., 1879, p. 337.

17. NABOKO, S. I. — *Investigations of the sublimates of the Klyuchevskoy volcano*. Bull. Acad. Sci. U.S.S.R., Ser. Geol., 1945, No. 1, p. 50.

18. NOVOGRABLENOV, P. T. — *The catalogue of Kamchatka's volcanoes*. Bull. Russian Geogr. Soc., 1932.

19. PIIP, B. I. — *On the names of Ksudach volcano and Stübel's volcano*. Bull. Kamchatka Volcan. Station, 1941, No. 9, p. 26.

20. ——— — *The eruption of the Avacha volcano in 1938*. Bull. Kamchatka Volcan. Station, 1941, No. 10, p. 13.

21. ——— — *On the incandescent agglomerate flows of Avacha and on the type of eruption of this volcano*. Bull. Kamchatka Volcan. Station, 1946, No. 12, p. 18.

22. POPKOV, V. F. and SOSUNOV, N. F. — *The Activty of the Avachinski and Mutnovski volcanoes during the first three months of 1939*. Bull. Kamchatka Volcan. Station, 1941, No. 9, p. 5.

23. POPKOV, V. F. — *On the activity of Bilukay in 1938-1939*. Bull. Kamchatka Volcan. Station, 1946, No. 12, p. 29.

24. SOLOVIEV, A. — *The Kurile Islands*. Geographical Institute, Acad. Sci. U.S.S.R., 1946.

25. SOSUNOV, N. F. — *Observations on the activity of the Avachinski (Avacha) and Mutnovski volcanoes from April 1 to June 1, 1939*. Bull. Kamchatka Volcan. Station, 1941, No. 10, p. 10.

26. TOMITA, T. — *On the chemical composition of the Cenozoic Alkaline Suite of the Circum-Japan Sea Region*. Journ. Shanghai Science Inst., 1935, Sect. II, Vol. I, p. 227.

27. VLODAVETS, V. I. — *The chemical composition of the eruptive rocks of Kamchatka*. Bull. Kamchatka Volcan. Station, 1939, No. 5, p. 19.

28. ——— — *On the connection of Kamchatka volcanoes with seismic activity*. Bull. Kamchatka Volcan. Station, 1939, No. 6, p. 28.

29. ——— — *On the activities of the Kamchatka volcanological station*. Bull. Acad. Sci. U.S.S.R., Ser. Geol., 1945, No. 1, p. 40.

30. ——— — *On the chemical composition of Kamchatka magmatic province. Problems of mineralogy, geochemistry and petrography* (Volume dedicated to the memory of A. E. FERSMAN). Acad. Sci. U.S.S.R., Moscow, 1946, p. 339.

31. WASHINGTON, H. S. and KEYES, M. G. — *Rocks of the Pribilof Islands*. Amer. Journ. Sci., 1930, ser. 5, vol. 20, p. 321.

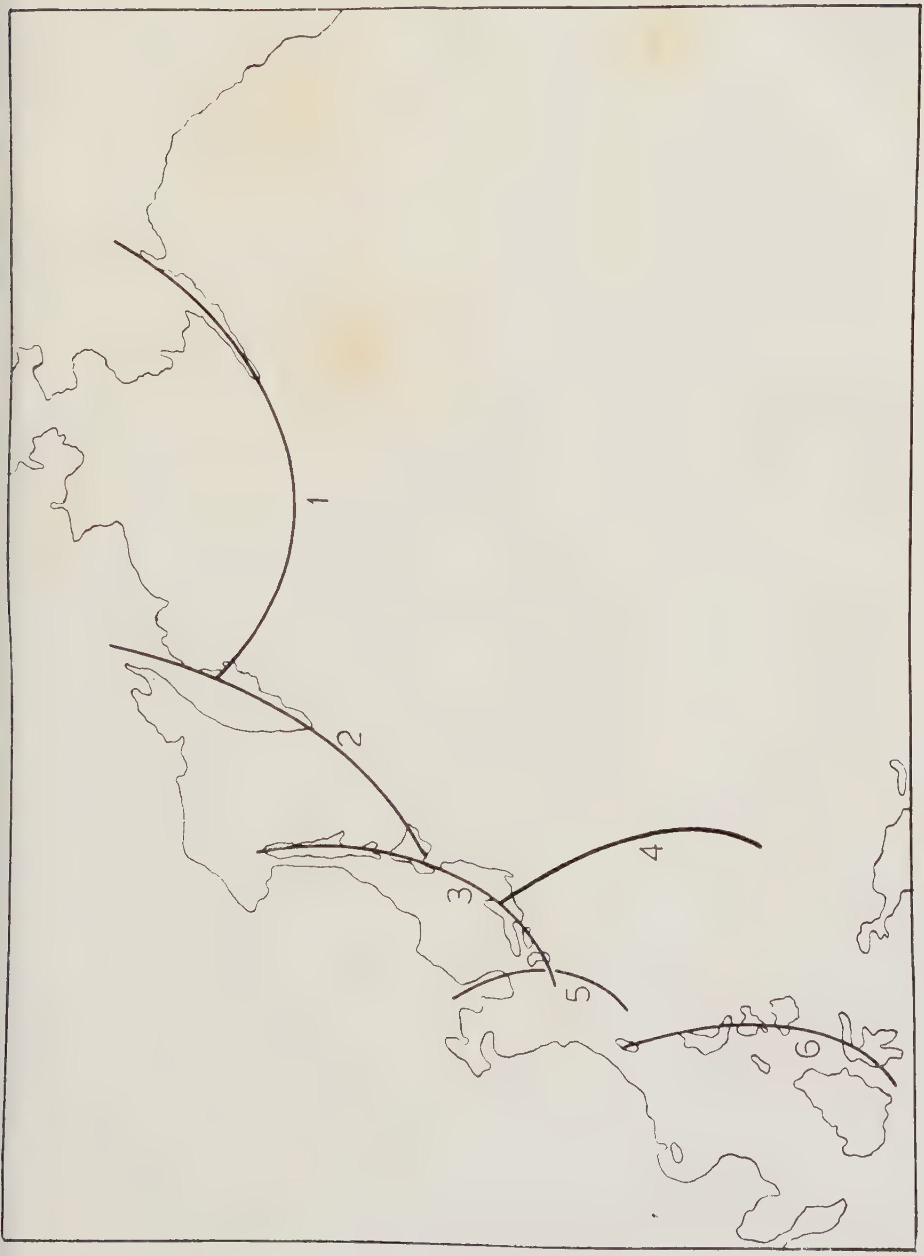

Fig. 1 - Map of the Northern part of the Pacific Ocean showing arcs festoon. Arcs: 1. Alaskan-Aleutian; 2. Kamchatka-Kurile; 3. Sakhalin-Japan; 4. Schichito-Bonin-Marianne; 5. Korea-Riukiu; 6. Philippines-Celebes.

Fig. 2 - Map of Kamchatka showing the principal volcanoes and the tectonic lines *(Zavaritsky* 1940).

Fig. 3 - The sketch of Klyuchevskaya Sopka (right), Kamen (middle) and Besymyannaya Sopka (left), (*Zavaritsky*, 1935, Fig. 12).

Fig. 4 - The sketch of Avacha Volcano (*Zavaritsky*, 1935, Fig. 3).

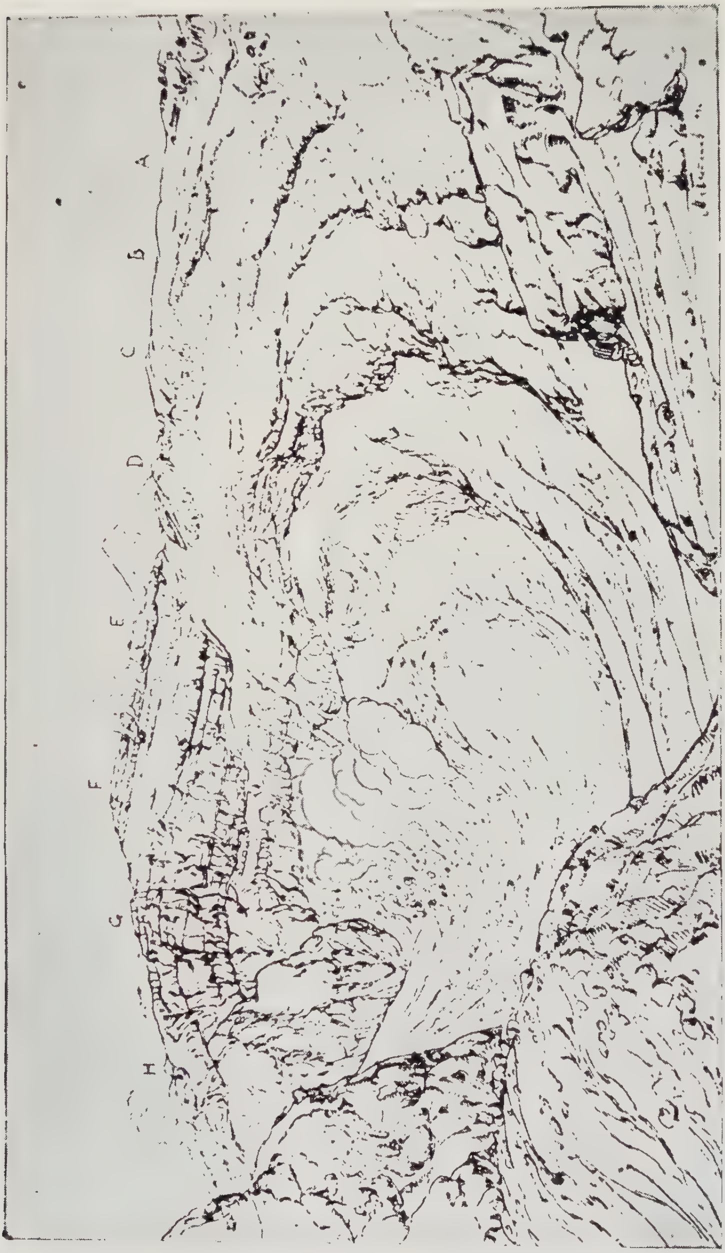

Fig. 5 - The sketch of the crater of Avacha volcano (Ibid. Fig. 5).

Fig. 6 - Seismic map of Kamchatka *(Gorskov* and *Popov* 1938, Fig. 1).

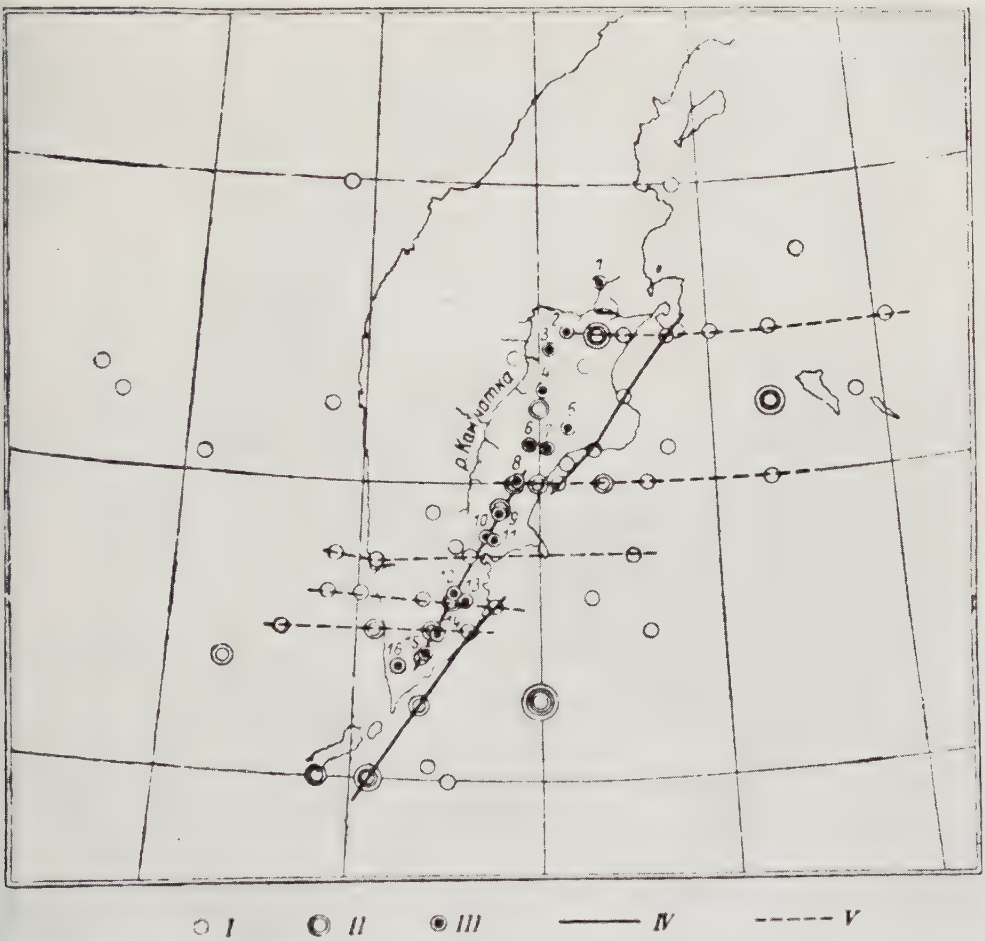

Fig. 7 - A map of active volcanoes and epicentres of earthquakes in Kamchatka (*Vlodavets*, 1939, Fig. 1).

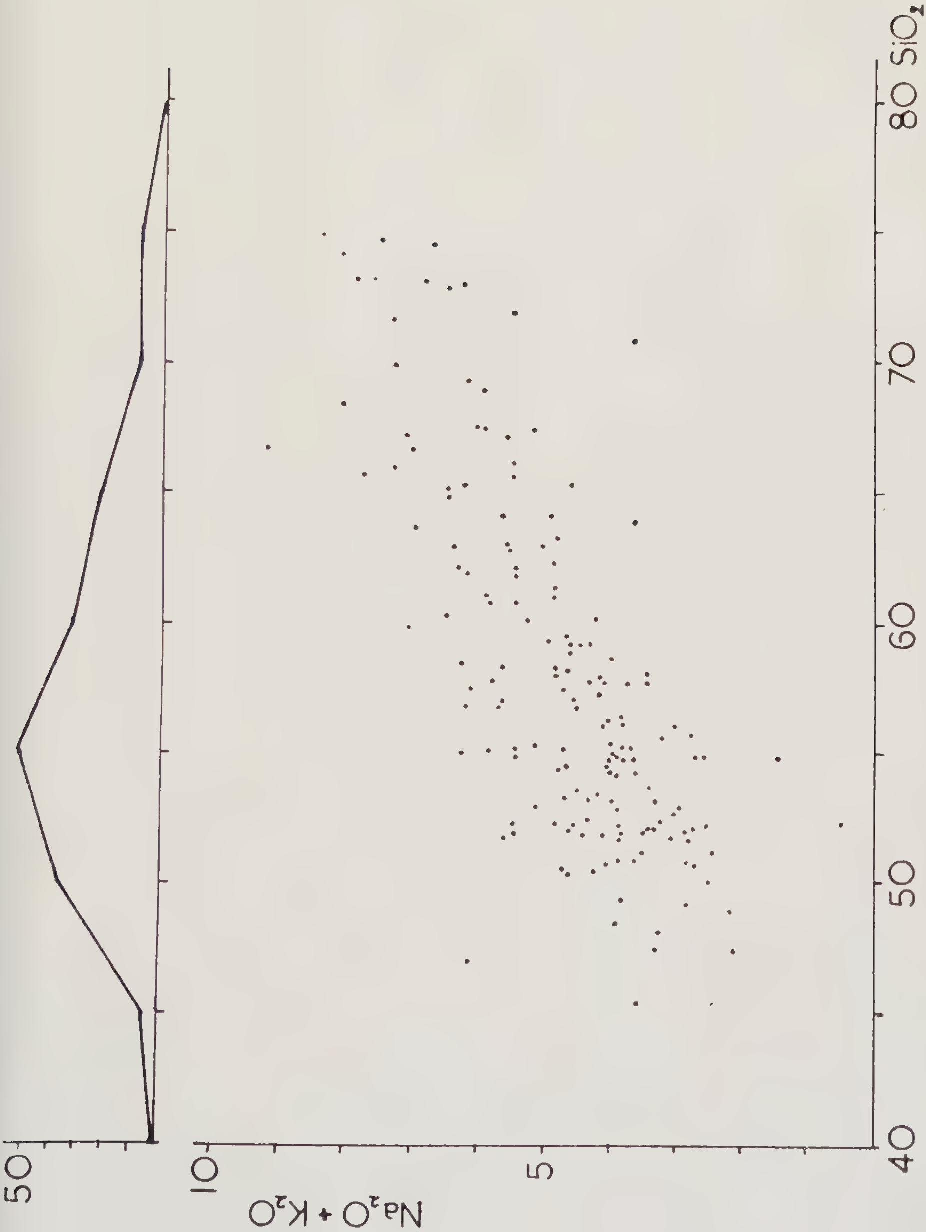

Fig. 8 - SiO_2 frequencies (above) and alkalies-silica correlation diagram (below) for Kamchatka's volcanic rocks.

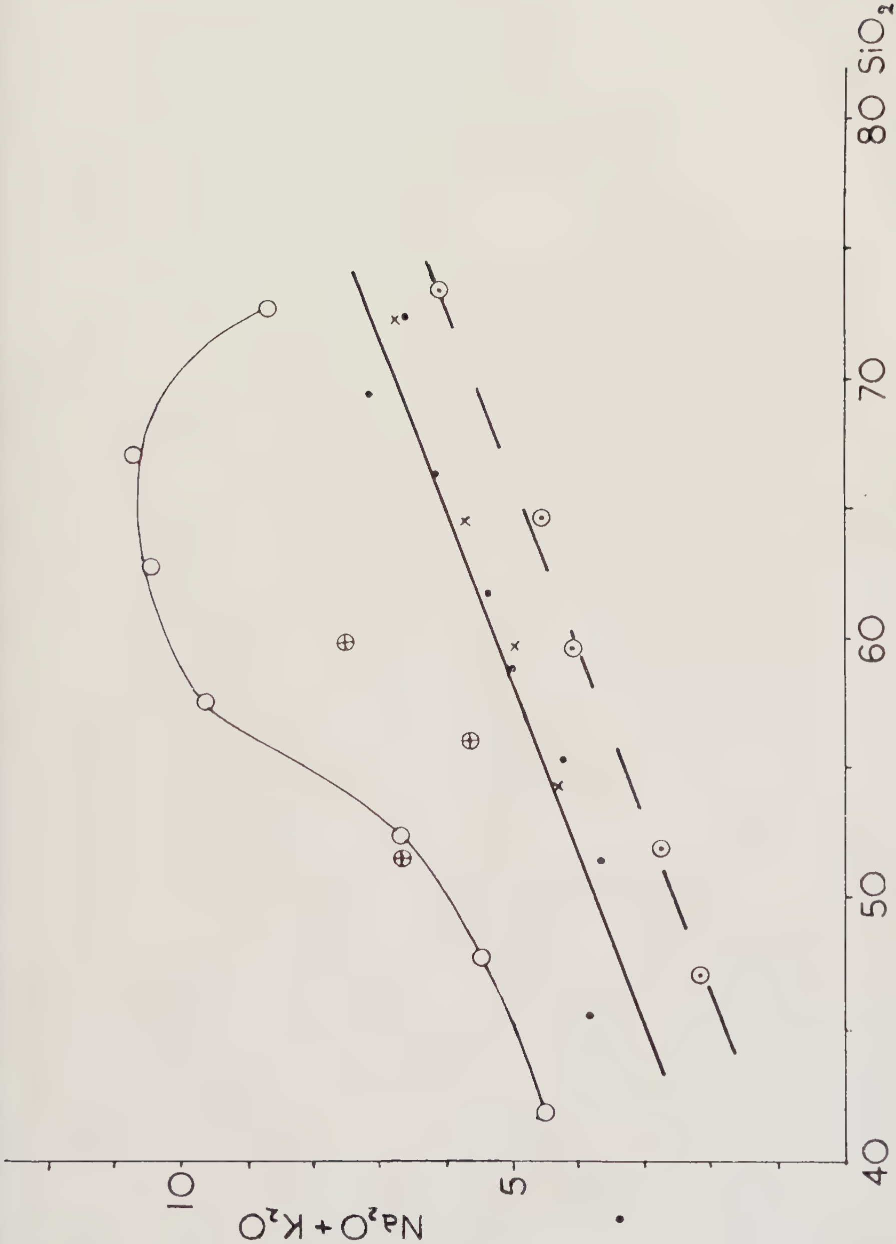

Fig. 9 - Alkalies-silica curves for the igneous rocks of Kamchatka (dots), Alaskan-Aleutian arc (diagonal crosses), Bogoslov Islands (vertical crosses in circles), Japan (dots in circles) and alkaline suite of the Trans-Japanese province (open circles).

32. WOLFF, F. von — *Der Vulkanismus*. Band II, Teil I, Stuttgart, 1929.
33. ZAVARITSKY, A. N. — *Some igneous rocks from the environs of Klyuchevskaia Sopka (Kamchatka)*. Mém. Soc. Russe Min., 1931, sér. 2, vol. 60, p. 153.
34. ——— — *Avacha volcano and its state in 1931*. Trans. Centr. Geol. & Prosp. Inst., Leningrad, 1935, No. 35.
35. ——— — *The northern group of Kamchatka Volcanoes*. Counc. Research Natur. Res. Kamchatka, 1935, No. 1, Acad. Sci. U.S.S.R.
36. ——— — *Linear distribution of the volcanoes of Kamchatka*. Abstracts of papers. Intern. Geol. Congress, Moscow, 1937, p. 136.
37. ——— — *On the volcanoes of Kamchatka*. Kamchatka's Collection. I. Acad. Sci. U.S.S.R., 1940, pp. 181-225.
38. ——— — *The geological map of Kamchatka*. Acad. Sci. U.S.S.R., 1941.
39. ——— — *The study of Kamchatka volcanoes*. 1942, p. 22.
40. ——— — *Volcanoes in the vicinity of Mergen and their lavas*. « *Obruchev's* Jubilee Volume », Acad. Sci. U.S.S.R., p. 9.
41. ——— — *The volcanic zone of Kurile Islands*. Vestnik Acad. Sci. U.S.S.R., 1946, No. 1, p. 41.

G. IMBÒ

Importanza delle determinazioni delle temperature d'irrigidimento delle lave

Nel 1935 intrapresi ricerche in situ sul raffreddamento delle lave fluenti vesuviane, ricerche che, presto interrotte per subentrate difficoltà, sono state riprese nel 1947, da un canto estendendole anche a lave fluenti etnee, e d'altro canto integrandole con misure in laboratorio. Per tutte le eseguite analisi le curve di variazione termica col tempo, oltre a particolarità che non è il caso di mettere qui in risalto, mostrano l'esistenza di un flesso a temperatura pressochè costante per lava della stessa origine nonchè della medesima età, ma variabile evidentemente con il variare delle dette condizioni e specialmente della prima. Mentre per la lava etnea del 1947 si è riscontrato il flesso nello intervallo termico 660°-680°, per le lave vesuviane del 1935 esso si presenta a temperature alquanto superiori ed aggirantisi fra i 760° e gli 800°. L'esame critico delle osservazioni permetterebbe di identificare la temperatura media del flesso con la temperatura che potrebbe essere denominata temperatura di irrigidimento nel senso che entro un ristretto intervallo termico adiacente ad essa il coefficiente di viscosità del prodotto esaminato raggiungerebbe valori tanto elevati da impedire il prolungarsi del fenomeno cristallogenetico: in corrispondenza del flesso si hanno difatti nelle curve di raffreddamento decisi aumenti nelle velocità di raffreddamento, derivanti da cessata somministrazione di calorie di fusione. Considerazioni inoltre sulle variazioni del coefficiente di viscosità di lave per lo più basiche con la temperatura condotte dal KANI, oltre a giustificare la suddetta interpretazione, consentono ancora di porre in rilievo l'importante deduzione di una diminuzione, a parità di tutte le altre condizioni, della temperatura di irrigidimento delle lave col diminuire della viscosità dei magmi da cui esse derivano.

Più opportunamente che non attraverso il solo esame chimico-petrografico, dalla osservazione delle temperature di irrigidimento può pertanto aversi un'idea od anche un numero indice del coefficiente di viscosità magmatico (*vero*, se eseguite in campagna coi dovuti accorgimenti, in quanto corrispondente a condizioni fisico-chimiche rispecchianti, più di quanto non lo consentano le misure in laboratorio, quelle effettive magmatiche; *apparente*, se eseguite in laboratorio per le evidenti diversità di condizioni con quelle precedenti), del quale coefficiente, la cui conoscenza, almeno approssimata, è indispensabile al vulcanologo nello studio di diversi problemi specialmente riguardanti i dinamismi eruttivi, è difficile se non impossibile ottenersi un idoneo, sia pur relativo, valore in base ai metodi di determinazione finora suggeriti, in quanto questi risultano spesso inadeguati e per lo più irrealizzabili.

G. IMBÒ

Carattere fondamentale nell'andamento delle variazioni annue nell'inclinazione del suolo all'Osservatorio vesuviano

Fin dal 1935 si sono incominciate all'Osservatorio Vesuviano osservazioni quotidiane sulle variazioni nell'inclinazione del suolo giovandosi di due livelle (con sensibilità di circa 2") disposte ortogonalmente su un pilastro parzialmente affondato nel tufo compatto del M. Somma. Sono state già rese note le prime deduzioni le quali, se pure debbono subire qualche ritocco, permettono tuttavia di rilevare l'alta importanza che misure del genere, preferibilmente continue, come già si pratica all'Osservatorio Vesuviano, assumono nelle zone vulcaniche, in quanto da esse possono aversi indizi dell'attività magmatica episuperficiale o profonda attraverso i conseguenti moti dell'edificio vulcanico. Una conferma dell'azione vulcanica sulle variazioni nell' inclinazione del suolo si ha ancora dall'esame comparativo degli andamenti annui per il decennio 1935 - 1944 e per il successivo triennio 1945 - 1948. Il comportamento pei due intervalli è difatti nettamente diverso. Mentre per il primo intervallo, caratterizzato da prevalentemente vivaci e quasi persistenti manifestazioni esplosive ed effusive, a parossismi intermittenti, le variazioni annue risultano piuttosto bizzarre; per l'altro, caratterizzato invece da assenza di fenomeni eruttivi in conseguenza dell'ostruzione del condotto (provocata da collassi, franamenti ed ancora favorita dalla disattivazione magmatica a sua volta derivante dalla più o meno notevole degassazione verificatasi nel corso del violento parossismo terminale del marzo 1944) esse rivelano una decisa regolarità non tanto nelle ampiezze quanto nel senso della deviazione apparente della verticale, come del resto si è constatato anche presso l'Osservatorio del Kilauea. L'importanza del rilievo ap-

pare notevole in quanto a sua volta da esso emerge la possibilità, attraverso osservazioni accurate e possibilmente estese a più stazioni opportunamente dislocate, di una previsione a più o meno breve scadenza della riapertura del condotto segnante l'inizio del nuovo periodo eruttivo vesuviano.

G. IMBÒ

Le recenti manifestazioni eruttive vesuviane

Più volte è stato messo in evidenza per il Vesuvio il suo caratteristico andamento eruttivo che nelle linee generali rimane sempre e pienamente confermato. Il susseguirsi degli *intervalli eruttivi* (decorrenti tra due successive fratturazioni del conetto intracraterico), col progredire del *periodo eruttivo* (ossia dell'intervallo compreso tra la riapparizione dei tipici fenomeni eruttivi in seguito alla riapertura della bocca di fuoco sul fondo del cratere e la ostruzione del condotto conseguente a violento parossismo, segnante la definitiva chiusura del periodo stesso), incominciato il 5 luglio 1913, è risultato sempre meno evidente per assenza di depressioni atte a delimitarli od anche per sovrapposizione di due o più intervalli. A partire dalla ripresa dell'attività successiva alla pausa eruttiva 1930-1933 possono essere distinti, fino al marzo 1944, ben 15 intervalli con successioni bizzarre nelle fratturazioni e senza apparenti predilezioni in quanto a direzioni interessate, generalmente radiali; non mancano però fratturazioni biradiali (tra cui le diametrali) ed anche le pluriradiali. Tra gl'importanti fenomeni del periodo eruttivo devono, per il loro carattere di eccezionalità, essere ricordati due che si riferiscono: il primo allo sgorgo nella primavera 1942 di due minuscoli rigagnoli lavici direttamente da bocche laterali dislocate lungo la fratturazione meridionale dell'eruzione del 1906; il secondo a particolare attività esplosivo-effusiva (1° novembre 1941) in relazione a sgretolamento del conetto provocato probabilmente da bombardamento aereo. Nel corso dell' undicennio 1933-1944, salvo complessivamente non oltre un anno, mai furono assenti i trabocchi lavici che completarono il riempimento del cratere del 1906, sopraelevando la piattaforma lavica in modo che le lave potettero riversarsi oltre che in Valle dell'Inferno (come già si era verificato in antecedenza, a partire dal 1926), anche secondo vari altri versanti. In complesso

si è molto al disotto del vero attribuendo a questo secondo intervallo del periodo eruttivo un volume totale delle lave emesse di 100 milioni di metri cubi.

L'ultimo tempo del periodo eruttivo è stato invece caratterizzato da assenza di attività effusiva. Dopo la recrudescenza eruttiva del 6 gennaio 1944 (inizio dell'ultimo intervallo eruttivo del periodo) con lave che si riversarono anche all'esterno lungo il fianco occidentale, a settentrione della ex stazione franante della Funicolare Vesuviana, si ebbero efflussi intracraterici per circa un mese e poi la attività esplosiva subì una graduale riduzione fino a che il 13 marzo, per ostruzione occasionale del condotto in seguito al collasso del conetto, cessò completamente. Con questo fenomeno può considerarsi incominciata la fase preeruttiva in quanto si può ritenere che esso (anche se non lo si volesse considerare già un effetto) avrebbe potuto rappresentare una causa determinante le particolari condizioni favorevoli per il presentarsi poi dei fenomeni eruttivi.

D'altronde l'analisi dei fenomeni sismo-eruttivi precedenti aveva già lasciato rilevare il probabile prossimo raggiungimento da parte delle materie ignee dell'attitudine a violente manifestazioni eruttive. Il parossismo, incominciato il pomeriggio del 18 colla brusca riapertura del condotto, che aveva già presentato nei giorni precedenti intermittenti parziali disostruzioni, presentò fenomeni nettamente distinguibili in quattro fasi.

I fase — Fase effusiva terminale (dalle 16^h del 18 marzo alle 17^h del 21), durante la quale si è avuta la distruzione dei due terzi dei due centri abitati di Massa e di San Sebastiano al Vesuvio ed ancora di estesi terreni coltivati. Il volume totale delle lave si aggira intorno ai 20 milioni di metri cubi e cioè presso a poco identico ai volumi relativi alle due precedenti eruzioni del 1872 e del 1906.

II fase — Fase delle fontane laviche (dalle 17^h del 21 marzo alle 12^h del 22), caratterizzata da violenti sollevamenti della colonna ignea fino ad oltre un chilometro di altezza da cui dipartivansi zampilli lavici in tutte le direzioni e ricadenti sui fianchi del Gran Cono. I proietti, durante tale fase, che hanno raggiunto le più alte quote (probabilmente intorno ai 5 Km.) per azione

del vento sono stati trascinati verso SE e si sono riversati nelle zone di Angri e Pagani, ossia ad oltre 16 Km. dall'asse eruttivo.

Furono distinte otto fontane, ciascuna avente una durata inferiore all'ora, ad eccezione dell'ultima che ebbe una durata di oltre cinque ore.

III fase — Fase delle esplosioni cosidette miste (dalle 12^h del 22 fino alla tarda sera del 23) e cioè con proiezioni di materiali scuri ed incandescenti e con sempre crescente prevalenza delle ceneri provenienti dal disfacimento delle materie ignee nonchè dal disgregamento delle pareti del condotto e delle parti terminali dell'edificio. I pini in ampie volute si elevarono fino ad altezze non inferiori ai 5 Km. e le ceneri si spinsero fino a Bari, Taranto ed anche in Albania, ossia fino ad una distanza di oltre 500 Km.

IV fase — Fase sismo-eruttiva (dalla notte sul 24 sino al 29) durante la quale si ripetettero intermittentemente crisi sismiche e crisi esplosive, ad intensità mediamente decrescente sino alla loro completa scomparsa.

Continuarono invero fenomeni sismici isolati che si sono presentati in generale con intermittenti addensamenti e rarefazioni sino a che dopo oltre un anno dall'eruzione sono cessati anche questi, almeno come fenomeni abituali.

La chiusura definitiva della bocca si verificò il 7 aprile, dopo svariate ostruzioni, in conseguenza di franamenti delle pareti crateriche, e successive riaperture.

Quando si verificherà l' inizio del nuovo periodo eruttivo? A questa domanda non è consentito dare una netta risposta; sono già trascorsi oltre quattro anni dall'inizio del periodo di riposo e nessun fenomeno particolare si è finora presentato che lasci presagire una, almeno immediata, riapertura della bocca di fuoco.

Dopo l'anzidetta cessazione dell'agitazione sismica successiva alla eruzione e salvo un breve periodo sismico del febbraio 1946, si è avuta calma sismica completa, interrotta ancora, con appena qualche lieve scossa, nel marzo-aprile dell'anno corrente. Nè gli altri osservati fenomeni potrebbero consentire allo stato presente evidenti deduzioni. Nè ancora un esame delle condizioni attuali, sulle basi delle effettuate ricerche statistiche relative alle vicende eruttive presentatesi al Vesuvio, a partire dagli inizi del secolo

XVIII, permette di ovviare almeno in senso indicativo alla accennata deficienza; vi sono motivi per cui già il vulcano avrebbe dovuto riprendere la sua abituale attività e motivi pei quali il periodo di riposo dovrebbe risultare relativamente lungo, ed anche, se si considera la sola influenza della durata (di ben 31 anni) del periodo eruttivo precedente (la più lunga nell'intervallo considerato), più lungo di quelli finora presentatisi. Quali motivi avranno la prevalenza? Finchè mancano indicazioni strumentali oppure finchè non si osserveranno fenomeni che lasceranno indubbiamente dedurre la progressiva riattivazione magmatica od anche il più o meno graduale sollevamento delle masse ignee nel condotto, non è consentito invero dare una risposta definitiva. Mi auguro di poter dare inizio al più presto allo studio termico di due fumarole intracrateriche, ambedue quasi certamente primarie, in modo che esso, integrato dalle altre indagini che si conducono all'Osservatorio, fondate: sulle osservazioni sismiche e microsismiche, sulla frequenza ed entità delle frane, sulle osservazioni delle variazioni nell'inclinazione del suolo relative all'Osservatorio ma estensibili a tutto l'edificio vulcanico, sulle osservazioni di eventuale attività tettonica intracraterica, possa consentire la soluzione dell'interessante proposto problema.

Resina, 8 agosto 1948.

G. IMBÒ

Considerazioni sulla presente attività del Vesuvio

(con 10 figure)

Le indagini sui dinamismi vulcanici non devono essere limitate a semplici annotazioni della successione più o meno completa dei fenomeni centrali e periferici propriamente detti, ma richiedono anche l'esecuzione delle dirette e minuziose osservazioni in molteplici campi di ricerche in modo che dalla coordinazione dei risultati possa riuscire da un canto meno ardua l'identificazione delle cause delle manifestazioni e d'altro canto attuabile financo una probabilistica formulazione di presagi, in relazione sia al tempo che allo spazio interessato da futuri fenomeni.

Sotto questo punto di vista deve essere considerata la discesa sul fondo del cratere vesuviano (Figg. 1 e 2) del 13 giugno, mirante in effetti alla realizzazione, la meno incompleta possibile, del vasto e complesso programma. Le difficoltà incontrate per l'effettuazione della discesa contribuiranno a giustificare la relativa incompletezza dei dati raccolti (1).

Delle osservazioni effettuate vengono esposti sinteticamente rilievi e risultati (2).

1° - Il fondo craterico è costituito prevalentemente da una piattaforma detritica cosparsa di massi lavici, disposta eccentricamente nella zona meridionale craterica e di forma grosso modo ellittica. Essa presenta una lieve pendenza a SE, in modo che il margine sud-occidentale, spingentesi solo in tale direzione fin sotto le ripide pareti crateriche, rappresenta la zona più bassa del fondo.

(1) G. IMBÒ - *Una discesa nel cratere del Vesuvio*. « Vie d'Italia », 1949.

(2) Per alcune necessarie incompletezze si è cercato di agevolare la comprensione del testo con idonee illustrazioni.

L'asse maggiore della piattaforma, corrente presso a poco secondo la direzione EW, ha una lunghezza di poco oltre i 60 metri, mentre l'asse minore normale al primo ha una lunghezza di circa 40 metri.

2° - Il contorno della piattaforma (Fig. 3) è molto irregolare ed è prevalentemente rappresentato dai margini delle basi di conoidi che si appoggiano fino a diverse altezze alle pareti crateriche.

3° - Mediante l'altimetro ed anche mediante metodo trigonometrico (con tacheometro dall' orlo e stadia, opportunamente disposta, sul fondo craterico) è stato possibile effettuare per la prima volta una relativamente rigorosa misura del dislivello tra orlo W e centro della piattaforma. Tenuto conto delle opportune correzioni, i due valori concordano e si ha pertanto:

$$\Delta h = \text{m. } 216{,}5$$

4° - Escludendo i valori stimati, nonostante una concordanza coi valori dedotti, e riferendosi invece al valore approssimato della profondità, calcolata con opportune considerazioni il 21 aprile 1944, si osserva che dal confronto tra il valore allora dedotto di circa m. 280 e quello ottenuto il 13 giugno emerge la conclusione di un sollevamento, tra le due date, del fondo craterico intorno a m. 60, in conseguenza del convogliamento verso la zona depressa, specialmente da parte delle precipitazioni, prevalentemente del materiale minuto delle conoidi.

5° - La concordanza tra le diverse misure di quota dell'orlo W, effettuate, sempre mediante l'altimetro, tra il 7 aprile 1944 ed il 13 giugno ultimo, oltre a mostrare una costanza, almeno approssimativa, dell'altezza, permette di assumere come quota di tale orlo il valore medio di

$$\text{m. } 1164 \pm 4.$$

Invero la quota dedotta (osservata + correzione) per tale orlo il 13 giugno è stata di m. 1169, la quale potrebbe ritenersi accettabile per il fatto che l'errore di chiusura, di m. 33, risulta pienamente giustificato dalla differenza tra le osservazioni di pressione, eseguite all' Osservatorio, alla partenza ed al ritorno. Si accetta pertanto l'ultimo valore, che si ritiene affetto da un errore di $\pm$ 5 m.

6° - La quota assoluta del centro della piattaforma risulta perciò di

$$\text{m. } 953 \pm 5,$$

mentre quella del già indicato punto più basso (alla base delle ripide pareti sud - orientali) può ritenersi non inferiore a m. 948 $\pm$ 5.

7° - Il confronto ancora tra le quote del fondo craterico: la attuale e quella osservata nel 1912 di m. 920 (3), ossia un anno avanti l'inizio dell'attività, lascia rilevare che, in riferimento al centro, la quota presentata all'inizio dell'attuale fase di riposo, contrariamente a quanto si era supposto, risultava non inferiore a quella che può dirsi finale per il periodo di riposo precedente 1906-1913.

8° - Questa considerazione, apparentemente contrastante con l'osservazione che mai, neanche nei primi giorni successivi all'eruzione del marzo 1944, fu rilevata la base detritica delle stratificazioni laviche del periodo eruttivo 1913-1944 mostrate dalle pareti orientali e settentrionali (tra SSE e WNW) (Fig. 4), risulta giustificata dal fatto che il sollevamento centrale della piattaforma è dovuto alla colmatura di una relativamente profonda depressione determinata dalla accentuata pendenza ad W del fondo craterico primitivo. Il sollevamento, prevalentemente per convogliamento, ad opera delle precipitazioni, del materiale detritico, cospicuo ad W, di circa 60 m. al centro, è stato piuttosto lieve o nullo ad E; in modo da giustificarsi da un canto l'inversione della pendenza attuale del fondo craterico rispetto a quella originaria e d'altro canto la constatazione della quota attuale del margine orientale della piattaforma craterica appena più elevata di quella osservata anteriormente alla ripresa, nel 1913, dell'attività eruttiva.

9° - Nei riguardi della profondità massima ossia della differenza tra quota del punto più elevato dell'orlo e del punto più basso del fondo risulta evidentemente indispensabile la conoscenza della prima quota. Anche per questa, corispondente presso a poco all'orlo ENE, sono state effettuate diverse misure me-

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(3) A. Malladra - *Il fondo del cratere vesuviano*. Rend. Acc. Sc. Fis. e Mat., Napoli, 1912.

— A. Malladra - *Nel cratere del Vesuvio*. Boll. della Soc. Geogr. Ital., 1914.

diante l'altimetro tra il 7 aprile 1944 ed il 20 settembre 1948. La concordanza dei valori, nel fare escludere variazioni apprezzabili di altezza, permettono di dedurre, come quota media del punto più alto dell'orlo, il valore di:

$$\text{m. } 1267 \pm 10.$$

Reputo opportuno oservare che il 21 aprile 1944 vennero eseguite, mediante tacheometro e stadia, misure della differenza di quota ($\Delta h'$) e della distanza orizzontale (D_M) tra il punto W e quello più alto dell'orlo, ottenendo rispettivamente i seguenti valori medi:

$$\Delta h' = \text{m. } 115{,}6\,; \; D_M = \text{m. } 574{,}5$$

Il valore di D_M rappresenta all'incirca anche la lunghezza dell'asse maggiore della proiezione orizzontale (grosso modo ellittica) dell'orlo craterico. Per la lunghezza dell'asse minore (D_m), presso a poco normale al primo, si ottiene in base ad un facile calcolo il valore di

$$D_m \simeq \text{m. } 484.$$

Il mancato accordo tra il valore di $\Delta h'$ indicato e quello deducibile dalle osservazioni con l'altimetro è perfettamente giustificato dall'errore di $\pm$ 15 m., da cui possono essere affette le seconde. Ammettendo, pertanto, come valore della differenza di altezza, quello avuto in base alle osservazioni tacheometriche, si ha come dislivello massimo il valore di poco inferiore a m. 340, che rappresenta presso a poco l'altezza della parete orientale, la quale, salvo per un tratto terminale di una cinquantina di metri, svasata per fenomeni di deiezione e per altro tratto alla base, di un centinaio di metri, relativamente alle conoidi, può ritenersi grosso modo verticale.

10° - La determinazione di quote sicure, assolute o relative, del fondo, come dei vari punti dell'orlo, riesce oltremodo utile nelle indagini sui meccanismi eruttivi in genere ed in particolare per il Vesuvio. Senza invero tenere conto del carattere dominante rivelato dalla successione dei fenomeni eruttivi vesuviani, la ripresa dell'attività potrebbe verificarsi sia in modo violento che in modo tranquillo. A questa duplice possibilità sono eviden-

temente connessi tipici fenomeni tettonici interessanti zone notevolmente ristrette od anche variabilmente estese, a seconda, invero, di altre condizioni. La presenza eventuale di tali fenomeni consentirebbe pertanto la formulazione di previsioni, in relazione alle manifestazioni iniziali del periodo eruttivo, non solo in ordine al tempo ma anche nei riguardi dell'ubicazione e della natura di esse. Sono noti i fenomeni tettonici che hanno preceduto la tranquilla ripresa di attività del 1913. Essi consistettero prevalentemente nella formazione di scoscendimenti, di avvallamenti imbutiformi manifestatisi fin dal 1910 e derivanti dall'assottigliamento del tappo ostruente il condotto eruttivo. Finora nessun indizio di deformazioni almeno sensibili, nè per gli orli che presentano le medesime quote rilevate con l'altimetro fin dai primi giorni successivi all'eruzione, nè per il fondo, le cui modificazioni sono derivanti esclusivamente dall'azione combinata dei franamenti e delle precipitazioni; ma la istituzione di opportuni capisaldi sul fondo, sulle pareti, sugli orli gioverà a rendere maggiormente individuabili eventuali variazioni relative di altezza, in modo da integrare, come già si era praticato nel corso del periodo eruttivo precedente, le osservazioni di deviazione apparente della verticale condotte all'Osservatorio e che eventualmente darebbero indizio delle sole deformazioni interessanti quasi per intero l'edificio vulcanico.

11° - Facendo notare che in nessun punto del fondo vi sono attualmente manifestazioni fumaroliche, si osserva che l'attività fumarolica dell'interno craterico può dividersi in tre gruppi:

I) - fumarole delle pareti;
II) - fumarole marginali settentrionali;
III) - fumarole sud-occidentali.

12° - Le fumarole delle pareti sono tutte già note. La principale (per continuità e copiosità delle esalazioni che danno spesso luogo alla formazione di un'esile nubecola sopraelevantesi sul cratere e visibile anche a distanza) è rappresentata da una fumarola (Fig. 5) aprentesi in una zona fessurata dello strato lavico relativo a lingua di lava debordata a NW nel marzo 1944.

Oltre a questa si hanno ancora: l'allineamento sud-occidentale di fumarole sviluppantisi mediamente secondo una curva di

livello (batteria sud-occidentale) già attivo anche nel corso dei precedenti periodi di riposo ed eruttivo; e qualche fumarola isolata prevalentemente nella zona meridionale. Dal comportamento di queste fumarole disposte per lo più in prossimità dell'orlo ed in relazione ad osservazioni dirette, almeno per la batteria sud-occidentale, è lecito arguire che si tratti in tutti i detti casi di fumarole a vapore acquo.

13° - Il 2° gruppo consiste in fumarole (Fig. 6) disposte lungo la traccia della soluzione di continuità rappresentata dalla superficie di contatto tra materiale di frana e pareti settentrionali; ma interessanti anche queste ed il materiale detritico della frana. Ai due estremi dell'allineamento, rispettivamente l'inferiore a quota di circa m. 1010 ed il superiore m. 1050 all'incirca, si osservano le due fumarole già vagamente indicate come intracrateriche. Nei riguardi della loro attività, esse, dopo l'apparizione, come fumarole diffuse nella zona settentrionale del fondo craterico, negli ultimi mesi del 1944 (ove nei primi giorni successivi all'eruzione e fino al 7 aprile aprivasi un pozzetto in vistosa attività esalativa con basse proiezioni cineree), hanno subito alternative nella loro attività in dipendenza prevalentemente delle vicende dei franamenti a WNW. La copertura degli spiragli nel secondo semestre del 1945 determinò la cessazione dell'attività che riprese appena dopo le vistose frane (4) dal detto orlo specie del febbraio 1946, e si localizzò alcuni mesi dopo presso a poco lungo la zona sopraindicata. Nella giornata di osservazione, come già in precedenza, la fumarola inferiore (A) (Fig. 7), a distanza, si presentò disattiva, mentre da vicino si sentiva un lieve sibilo, accompagnato anche da un lieve tremito, rivelato da agitazione dell'ago di un galvanometro. Questo tremito è probabilmente provocato dall'eccitazione delle pareti in conseguenza della fuoruscita, attraverso gli svariati crepacci, degli aeriformi, tra i quali nettamente si avverte l' HCl. La velocità dell'esalazione risulta di 1,60 m/sec., largamente giustificata dalla temperatura e dalle condizioni fumaroliche. Tra le diverse misure eseguite, con differenze non oltrepassanti i 5°-10°, il più alto valore è di

(4) I franamenti determinarono la formazione di una sella (Figg. 8 e 9), dalla quale ha avuto inizio la discesa.

$$T = 293^0$$

La seconda fumarola (B) era prevalentemente a vapor acqueo, ma vi si avvertiva anche l' HCl. Da essa elevavasi una esile nubecola e la sua temperatura risultò di

$$T = 100^0$$

14° - È stato inoltre individuato presso il fondo craterico sud-occidentale un campo solfatarico (Fig. 10). Questo interessa diffusamente una conoide che sin dai primi giorni successivi all'eruzione, nel suo costituirsi, seppellì una frattura aprentesi sul fondo la quale partiva precisamente dalla base sud-occidentale, dirigendosi prima a N per poi convergere verso il pozzetto della zona settentrionale. Dalla frattura elevavansi ad intermittenza fumi azzurrognoli. L'attività solfatarica presente può ritenersi pertanto una continuazione della passata attività.

15° - Che con alta probabilità le manifestazioni fumaroliche attuali del 2° e 3° gruppo, continuazione dell'attività osservata sul fondo nel corso del periodo di transizione tra la fine della eruzione e l'inizio del periodo di riposo, dipendano da attività magmatica, può dedursi dalla considerazione di una centralità dell'attività del pozzetto, in quanto grossolanamente segnante col suo centro la traccia dell'asse eruttivo. Questa deduzione deriverebbe oltre che dalla coincidenza approssimativa tra la posizione della bocca eruttiva avanti l'eruzione e pozzetto, anche dalla considerazione sia dell'irradiamento da questo dell'attività intracraterica post-eruttiva che della divergenza dal pozzetto in senso radiale a NE di un dicco, partente da qualche decina di metri dal bordo, sopraelevantesi ancora per altrettanto ed incuneantesi nelle stratificazioni laviche della parete nord-orientale. L'osservazione di questo dicco, mentre da un canto giova a decisamente confermare, per la constatata continuità delle manifestazioni, l'attributo di *primarie* alle attuali fumarole dei due sopraindicati ultimi gruppi, risulta d'altro canto ancora interessante perchè permette di avere una chiara rivelazione della genesi, in quanto, pur non potendo stabilire una data precisa, esso si sarebbe sicuramente formato in seguito a fratturazione radiale delle sole stratificazioni laviche dei primi anni del periodo eruttivo 1913-1944.

Le precedenti considerazioni mostrano pertanto l'importanza delle dirette e continue osservazioni termo-chimiche-mineralogiche dei due gruppi fumarolici.

16° - La effettuata constatazione giova a dare una spiegazione del diverso carattere delle due principali fumarole del 2° gruppo. Mentre le *A* è difatti anidra, la *B*, come è stato detto, può essere considerata tra le fumarole a vapore acqueo, la cui presenza, oltre che per la presenza della nube, è resa evidente specialmente dai vistosi fenomeni di condensazione sulle pareti stesse della fumarola e sui nostri abiti.

Nel presupposto di un'unica origine per le fumarole della zona, il duplice comportamento potrebbe ricevere una esauriente spiegazione con l' ammissione della interposizione di lama acquea (5) tra sorgente e superficie solamente per la fumarola superiore. Anzi una tale considerazione permetterebbe di dedurre, sulla scorta anche delle osservazioni a distanza, una crescente attività per tale zona fumarolica, in quanto, all'inizio della ripresa dell' attività fumarolica della zona (dapprima intermittente, a causa delle frequenti ostruzioni e ricoprimenti, e poi pressochè continua dai primi mesi del 1945), l'attuale fumarola *A*, unica fumarola della zona, pur migrante, dava luogo a visibili esalazioni. L'estensione della zona, nonostante la sempre maggiore potenza dello strato detritico ed il conseguente maggior percorso degli aeriformi, ed ancora la successiva, quasi permanente scomparsa della nube per la *A*, dovrebbero pertanto essere ritenuti una conseguenza del graduale medio aumento del raggio della superficie di fondo della falda acquea sino ad intersecare la superficie della conoide con le conseguenze evidenti nell'attività. Mentre inizialmente per la fumarola *A* le esalazioni si arricchivano di vapore acqueo nell'attraversare la lama acquea, con superficie di fondo data dalle condizioni di eguaglianza tra acqua permeata ed acqua evaporata; con la successiva intensificazione od anche progressivo avvicinamento della sorgente verrebbe completamente giustificata l'estensione della zona termica e la scomparsa della nube fumarolica (nell'ammissione però che le esalazioni originarie siano state e siano anche attualmente anidre). Si

(5) G. Imbò - *Vapore acqueo nelle esalazioni fumaroliche.* Bull. Volc. N.os 23 à 26, 1930.

sarebbe qui in presenza evidentemente di salti termici nel tempo e nello spazio che già sono stati ritenuti presso altre zone fumaroliche (6) come indizi di analoghe variazioni dell'attività.

17° - Riesce intanto anche utile un confronto con le osservazioni termiche eseguite sia al presente in altre zone fumaroliche esterne, sia nel passato nell'interno del cratere ed in occasioni analoghe alle attuali.

Mentre in relazione alle prime, pur essendo state osservate nello stesso giorno (13 giugno) alle due principali (e cioè orlo occidentale craterico e margine occidentale della valanga calda costeggiante ad W la colata lavica del 1944 appena a monte della cima del Colle Margherita, trascurando le manifestazioni fumaroliche lungo il versante meridionale, perchè, a quanto sembra, risulterebbero indipendenti da quelle precedenti e dalle intracrateriche) temperature praticamente eguali a quelle osservate per la fumarola *A* e cioè rispettivamente 293° e 300°, non è consentito stabilire, per assenza di altre contemporanee osservazioni, una conformità o difformità negli andamenti termici; per le osservazioni invece eseguite nel 1911 e nel 1912 alla fumarola gialla, che, secondo la descrizione fattane dal MALLADRA, potrebbe ritenersi analoga a quella attuale dell'allineamento settentrionale, si propenderebbe per un' identica interpretazione. La differenza tra le due temperature, quella del 1911 di 126° e l'altra del 1912 di circa 300°, come al presente per la *A*, anzichè essere attribuita ad un salto termico nel tempo, come sarebbe lecito arguire dalle considerazioni del MALLADRA (7), deriverebbe da un salto nello spazio; nell'ammissione cioè di una stazionarietà negli andamenti termici, (limitatamente però all' intervallo decorrente tra le due considerate date) le osservazioni vennero eseguite non precisamente nel medesimo punto, ma quelle del CAPPELLO nella zona esterna all'intersezione della superficie di fondo, mentre le altre del MALLADRA nella zona centrale.

18° - Nei riguardi dell'altra zona fumarolica ossia del campo solfatarico, con temperature riscontratevi non superiori ai 94°, il cambiamento del carattere rispetto a quello del precedente gruppo,

(6) G. IMBÒ - *Sulle osservazioni termiche di fumarole nell'isola di Vulcano.* Ann. dell'Oss. Ves. IV Sez., Vol. III, 1935.
(7) Vedi (3).

col quale avrebbe in comune l'origine, è da attribuirsi alla copertura detritica che giustifica l'incompleta ossidazione dell' H_2S (la cui presenza è perfettamente discernibile), la produzione di H_2O che stilla dappertutto nelle anfrattuosità, nelle crepe, al disotto del compatto e duro manto, cosparso di copiose efflorescenze saline bianche e gialle ed ancora la deposizione di solfo. Per questo gruppo non è possibile eseguire alcuna deduzione sul suo andamento termico, ma si è sicuri che le osservazioni future, eseguite ad intervalli quanto più brevi possibili e con opportuni criteri, contribuiranno a chiarire alcuni aspetti dell'attività fumarolica intracraterica, nonchè a rendere meno difficoltose le indagini sulle relazioni con l'attività magmatica.

19° - Le diverse considerazioni che traggono invero pretesto dalla discesa sul fondo craterico del 13 giugno, mostrano l'indispensabilità di ricerche complesse e condotte negli svariati possibili campi, sia in situ che in Osservatorio. Intanto però può affermarsi che, nonostante il denunziato aumento di attività delle fumarole interne — tenuto conto dell'assenza di deformazioni che possono comunque dare una testimonianza di un particolare stato di tensione o del raggiungimento di esigui spessori per il setto soprastante le masse magmatiche del condotto, e potrei ancora aggiungere della presenza nei fenomeni osservati quotidianamente allo Osservatorio o dall'Osservatorio (deviazione apparente della verticale, agitazione sismica o microsismica, frane . . .) del carattere normale — la ripresa dell'attività del Vesuvio non può considerarsi immediata.

Fig. 1 Conetto eruttivo nel settore sud-occidentale della vasta piattaforma lavica all'orlo del cratere, nel febbraio 1944. Risulta appena distinguibile il riversamento lavico del 6 gennaio 1944 dal bordo occidentale craterico, a sinistra della stazione abbandonata (sul prolungamento della linea della funicolare). A destra si osservano: appena sottostante l'orlo la capanna vedetta dell'Osservatorio e le lave debordate lungo il fianco meridionale negli ultimi mesi del 1941. In fondo le pareti del Somma.

Fig. 2 - Cratere vesuviano successivo all'eruzione del 1944, fotografato da un aereo militare (Accademia Aeronautica). A sinistra la sella (orlo nord-occidentale) da cui è stata effettuata la discesa. Di fronte la parete orientale, alla cui base è appena visibile la cima di una conoide. In fondo pareti del Somma. 20 aprile 1947.

Fig. 3 - Fondo del cratere. Estremità nord-occidentale della piattaforma, delimitata dalla base della corrispondente conoide, percorsa nella discesa sul fondo. Si osserva in alto a destra la conoide detritica orientale. 13 giugno 1949.

Fig. 4 - Parete nord-orientale craterica, mostrante nettamente la stratificazione delle colate intracrateriche del periodo eruttivo 1913-1944. Alla base (a destra) si osserva l'estremità settentrionale di una bicipite conoide, che ebbe accentuato e rapido sviluppo in seguito ai copiosi franamenti del 18-19 settembre 1948. A sinistra, base della conoide sud-occidentale, ai cui margini con la parete craterica osservasi la fumarola principale (A) del gruppo settentrionale, priva di fumi.
Dall'orlo occidentale craterico, 8 giugno 1949.

Fig. 5 - Parete settentrionale craterica. A sinistra si osservano: in alto la fumarola isolata tra crepacci dello strato lavico del marzo 1944; in basso i fumi del campo fumarolico interessante il margine tra conoide nord-occidentale e parete craterica.
Dall'orlo occidentale craterico, 8 giugno 1949.

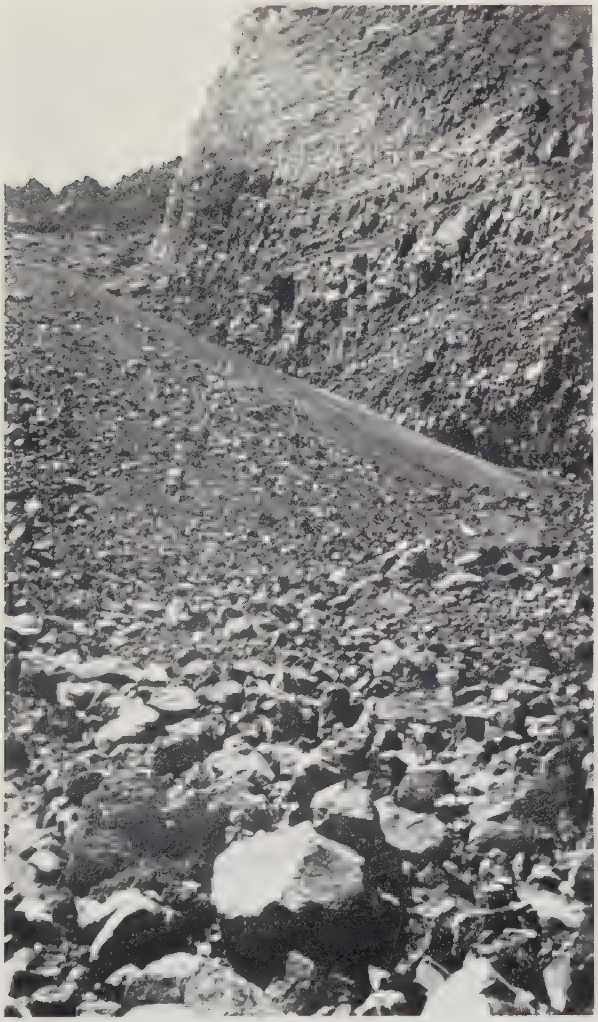

Fig. 6 - Allineamento fumarolico al margine tra conoide nord-occidentale e parete settentrionale craterica. In alto a sinistra orlo nord-occidentale craterico. Dal fondo craterico, 13 giugno 1949.

Fig. 7 - Fumarola principale (A) intracraterica ad esalazioni invisibili del gruppo marginale settentrionale.
13 giugno 1949.

Fig. 8 - Talus e costole nord-occidentali, segnanti il percorso della discesa del 13 giugno 1949. Copiosi fumi sono emessi dalle fumarole del gruppo settentrionale, e specialmente dalla fumarola (A).
Dall'orlo meridionale, 1947.

Fig. 9 - Talus nord-occidentale.
Appena sottostante una corrente lavica del marzo 1944 (visibile in alto) presso il bordo nord-occidentale si notano gli strati alterni di lave e scorie incoerenti.
13 giugno 1949.

Fig. 10 - Parete occidentale craterica ed in primo piano margine settentrionale del campo solfatarico interessante prevalentemente la conoide, di cui osservasi (in basso a sinistra) solo parte della base, segnante, con i resti della demolita conoide, il contorno occidentale della piattaforma craterica.
Dal fondo craterico, 13 giugno 1949.

NÉCROLOGIES

CHARLES EDGAR STEHN

(1884 - 1945 †)

In 1945 one of the most experienced volcanologists of his time, CHARLES EDGAR STEHN, passed away. He died on May 17th, 1945, after a second operation on an ulcer in the stomach at Dehra Dunn in British India.

From 1922 till 1940 STEHN has worked as a volcanologist of the Netherlands Indies Volcanological Survey. From 1926 till the day of the invasion of the Germans in the Netherlands, that is for fourteen years, he has been the leader of this unique volcanological institute. Being of German nationality, STEHN was interned on May 10th, 1940, together with the other Germans in the Netherlands Indies. At the outbreak of the war with Japan in 1941 STEHN was transported to British India, where he found his end, just before the finish of the war.

During his 18 years with the Netherlands Indies Volcanological Survey STEHN made 150 volcanological tours, making detailed studies of 41 active volcanoes in the Netherlands East Indies. Moreover, he went in 1937 to Rabaul at the request of the Australian Government, in order to report on the volcanic dangers menacing the capital of the Mandated Territory of New Guinea, in relation with the eruptions in Blanche Bay. During his European furlough in 1938 STEHN visited the volcanoes Vesuvius, Stromboli and Etna, making a special study of the organisation of the volcano-observations in Italy.

In 1922 STEHN studied the volcanoes of the Sangihe Islands, North of Celebes (Awu, Mahengetan, Api Siau, and Ruang), and those of the Minahasa (Mahawu and Lokon). In 1926 he investigated the Batur on Bali; in 1932 followed the study of five volcanoes on Flores, and in 1933-1934 he visited the Kerintji, Dempo, and Pematang Bata on Sumatra. In 1940 the Kaba and

again the Dempo on Sumatra were investigated. The new eruption cycle of the Krakatau in Strait Sunda since December 1927 was closely observed by STEHN and his collaborators. The remaining 14 volcanoes in the East Indies, studied by STEHN, are all situated on Java (Gedeh, Tangkuban Prahu, Papandajan, Kawa Kamodjang, Guntur, Diëng, Merapi, Lawu, Kelud, Bromo, Semeru, Lamongan, Raung, Idjen).

STEHN has published 34 papers and he composed 73 Bulletins of the Netherlands Indies Volcanological Survey. Moreover, several popular accounts of his work appeared in daily newspapers.

STEHN loved his profession as volcanologist; he was a keen observer and cautious with conclusions. He tried to apply new methods of investigation (thermocontacts for the « nuées ardentes » of the Merapi, tilt-meters). In many popular lectures he awakened the general interest for volcanology.

CAREER: Born at Altona, Germany, on November 10th, 1884. He studied from 1906 till 1910 at the T.N.S. of Karlsruhe, and from 1910 till 1914 at the University of Bonn, where he obtained his degree of Philosophical Doctor on July 8th, 1914. From 1914 till 1918 STEHN was a war-geologist in the German Army, and from 1919 till 1920 he was assistent for Geology at the University of Bonn. From 1920 till 1921 he worked as assistent of the institute of practical geology at Bonn (« Anstalt für angewandte Geologie »). Thereafter he went to the Netherlands Indies, where he joined the staff of the Bureau of Mines on November 7th, 1921. On February 27, 1922, he became conjunct to Dr. G. L. L. KEMMERLING, at that time leader of the Netherlands Indies Volcanological Survey. Here STEHN finally found his real profession, volcanology. Four years later, on May 26th, 1926, he was appointed leader of this survey.

The Netherlands Indies Government declared its special contentment for STEHN's excellent services in relation with the Merapi-guarding during the increased activity of the volcano in 1934.

STEHN went twice on furlough to Europe, first in 1930-1931 and for the second time in 1938. In 1926 he was one of the

delegates from the Netherlands Indies to the Pacific Science Congress at Tokyo. In 1937 he studied the volcanism of the Rabaul area at the request of the Australian Government. The second worldwar brought an end to his successful work as a volcanologist in the Netherlands Indies.

Publications by Dr. Ch. E. Stehn

1) 1923 *Beiträge zur Kenntnis des Bathonien und Callovien in Südamerika.* N. Jahrb. f. Min. etc., Beil. Bd *49*, 52-158, 1923.

2) 1925 *De aardbeving van Maos op 15 Mei 1923.* Vulk. & Seismol. Meded. No. 8, Dienst Mijnbouw Ned. Indië, Batavia 1925.

3) 1926 *Volcanological Work in the Dutch East Indies during 1923-1926.* Proc. 3rd. Pac. Sci. Congr., Tokyo 1926. Vol. I, pp. 718-734.

4) 1927 a *Devonische Fossilien von holländisch Neu-Guinea.* Wetensch. Meded. No. 5, Dienst Mijnb. Ned. Indië, Batavia 1927.

5) 1927 b *Vulkanische Ereignisse.* Zeitschr. f. Vulk. 1927, II (1926-1927), pp. 41-52.

6) 1928 a *Miniatur Lavaströme und Lavaspratzen im Papandajan Krater.* Centralblatt f. Min. etc., Abt. B. 1928, 4, 224-227.

7) 1928 b *De Batoer op Bali en zijn eruptie in 1926.* Vulk. & Seism. Meded. No. 9, Dienst Mijnb. Ned Indië, 1928, 1-67.

8) 1928 c *The Geology and Volcanism of the Krakatau Group.* Zeitschr. f. Vulk., *12*, pp. 332-336.

9) 1929 a *The Geology and Volcanism of the Krakatau Group.* (Repr. from « Krakatau », published for the 4th Pac. Sci. Congress, Java 1929, pp. 1-48).

10) 1929 b *Tangkoeban Prahoe.* (Excursion Guide B 3 of the 4th Pac. Sci. Congress, Java 1929, 22 pages).

11) 1929 c *Kawah Kamodjang.* (Excursion Guide C 2 of the 4th Pac. Sci. Congress, Java 1929, 13 pages).

12) 1929 d *Keloet,* (Excursion Guide E 2a of the 4th Pac. Sci. Congress, Java 1929, 37 pages).

13) 1929 e In collaboration with J. H. F. Umbgrove: *Bijdrage tot de geologie der vlakte van Bandoeng.* Tijdschr. Kon. Ned. Aardr. Gen., 2.de serie, *46*, 1929, 14 pages.

14) 1929 f *Einige Mitteilungen über den Vulkanologischen Dienst in Niederländisch Indien und seine Arbeiten*. Bull. Volc. Nos. 19 à 22, 1929, VIe année, Napoli 1933, pp. 13-20.
15) 1930 *Gids voor Bergtochten op Java*. Edited by the Neth. Ind. Soc. for Mountain Sport.
16) 1931 *Land - und Unterseevulkane, eine Wanderung durch die Niederländisch Indische Vulkanwelt*. Die Naturwissensch. 21 Aug. 1931, *19*, pp. 723-724.
17) 1932 *Schalenkogels van vulkanen op Java*. De Mijningenieur, 7, Bandung, 1932, pp. 125-132.
18) 1933 a *Gids voor Bergtochten op Java*. Second enlarged edition, edited by « Ned. Ind. Ver. voor Bergsport », Batavia, 1933, 188 pages.
19) 1933 b *Fünfzig Jahre Krakatau*. Die Umschau in Wiss. und Techn. Aug. 19th 1933, *37*, 34, pp. 659-663.
20) 1933 c *The status of the Volcanological Service of the Netherlands Indies*. Vth Pac. Sc. Congr. Canada 1933, Vol. 3, A. 7.18, pp. 2355-2356
21) 1933 d *Het praktische nut van het vulkanologisch onderzoek in Nederlandsch Indië*. De Mijningenieur *8*, 10. Bandung, 1933, pp. 178-183.
22) 1934 *Die semi-vulkanischen Explosionen des Pematang Bata in der Soeoh Senke (Süd-Sumatra) im Jahre 1933*. Natuurk. Tijdschr. v. Ned. Indië, *94*, 1, 1934, pp. 46-69.
23) 1936 a *Het gloedwolk gevaar bij den G. Keloet en de bescherming daartegen*. De Bergcultures *10*, 23-24, pp. 715-723 and 747-757, 1936.
24) 1936 b *Beobachtungen an Glutwolken während der erhöhten Tätigkeit des Vulkans Merapi in Mittel-Java in den Jahren 1933-1935*. Hand. v. h. 7e Ned. Ind. Natuurw. Congr. Batavia, 1936, pp. 647-656.
25) 1936 c *Het eruptie gevaar van den G. Semeroe voor de ondernemingen op de vulkaanhelling*. De Bergcultures *10*, 29, 1936, pp. 1184-1191).
26) 1936 d *Vulkanische verschijnselen in Ned. Indië in 1935*. Natuurk. Tijdschr. v. Ned. Ind. *96*, 3, pp. 149-187, 1936.
27) 1937 a *Vulkanische verschijnselen in Ned. Indië in 1936*. Natuurk. Tijdschr. v. Ned. Indië *97*, 5, pp. 98-108, 1937.
28) 1937 b *Die Auer-Industrie-Maske 747 bei der Vulkanbewachung in Niederländisch Indien*. Die Gasmaske, *9*, pp. 145-148, Berlin 1937.
29) 1938 a *Bemerkungen zu der Arbeit von* E. WASMUND : « *Vulkanoklimatischer Melanientuff am Caldera-See, Danu Batur auf Bali (Insulinde)* ». Geol. der Meere und Binnengewässer Bd, 2, Heft 1, pp. 153-156, 1938.

30) 1938 b *Vulkanische verschijnselen in Ned. Indië in 1937.* Natuurk. Tijdschr. v. Ned. Ind., *98*, 3, pp. 112-128, 1938.
31) 1939 a *Het vulkanologisch onderzoek in Nederlandsch Indië.* Jubileum nummer « Mijnbond », Bandung, Juli 1939, pp. 57-61.
32) 1939 b *De nieuwe dieptekaart van het Toba-meer (Noord-Sumatra) van Drost & Beckering.* De Ing. Ned. Indië, Sept. 1939, *6*, 9, Sect. IV, pp. 121-126.
33) 1940 a *Vulkanische verschijnselen in Nederlandsch Indië in 1938.* Natuurk. Tijdschr. v. Ned. Indië, *100*, pp. 7-35, 1940.
34) 1940 b *Vulkanologische onderzoekingen in Oost en Midden Flores.* Vulkanologische en Seismologische Mededeelingen No. 13, Batavia 1940, 92 pages.

The following 73 numbers of the Bulletin of the Netherlands Indies Volcanological Survey were written by STEHN:

Nos. 1-28	(1927-1929),	pp.	1-136;
Nos. 29-36	(1930),	pp.	1-31;
Nos. 49-60	(1931-1932),	pp.	69-142;
Nos. 61-74	(1933-1935),	pp.	1-183;
Nos. 75-79	(1936-1937),	pp.	1-60;
Nos. 81-83	(1937-1938),	pp.	67-97;
Nos. 86	(1938),	pp.	123-140;
Nos. 87-88	(1939),	pp.	1-32.

R. W. VAN BEMMELEN

ANTONINO LO SURDO

(1880 - 1949 †)

Le 7 Juin 1949 décédait à Rome le Prof. ANTONINO LO SURDO, Directeur de l'Institut de Physique de l'Université de Rome, Professeur de Physique supérieure et Directeur et fondateur de l'Institut National de Géophysique à Rome.

L'Italie avec le départ de A. LO SURDO perd un grand physicien et un passioné géophysicien.

La nécrologie du Prof. LO SURDO a été écrite par le Hon. Prof. E. MEDI (1), qui a dessiné lumineusement sa figure d'homme et de savant. Je crois qu'on ne puisse dire mieux.

Je rappellerai seulement la période 1906-1908, que LO SURDO passa à Naples auprès de l'Institut de Physique du Globe de l'Université de Naples, dirigé à ce temps-là par le Prof. CIRO CHISTONI.

En 1906, A. LO SURDO occupa dans le susdit Institut, alors Observatoire Météorologique de l'Université, la place de Vice-Directeur.

Quoique l'Observatoire fût dépourvu de locaux et instruments à cause des ruines subies pendant les dernières années de la direction de PALMIERI et celle par intérim de SEMMOLA et VILLARI, A. LO SURDO commença ses recherches sur la radiation solaire, sur la radiation nocturne et sur la condensation de la vapeur d'eau dans les émanations de la Solfatare de Pozzuoli. Entretemps il projetait et faisait construire un appareil pour étudier l'influence du vent sur la quantité de pluie recueillie dans les pluviomètres.

Suivant le conseil du Prof. CHISTONI, LO SURDO accepta en 1908 la place d'aide auprès de la chaire de Physique expérimentale de l' Institut des Études supérieures de Florence et la direction de l' Observatoire Météorologique et du Musée des instruments anciens de Florence, en continuant ses études de géophysique.

Le Prof. GARBASSO, qui dirigeait alors l' Institut de Phy-

(1) Annali di Geofisica, Vol. II, n. 2, 1949, Roma.

sique de Florence, l'aurait voulu come collaborateur pour la Géophysique, mais LO SURDO accepta en 1919 la chaire de Physique supérieure de l'Université de Rome. Toutefois il n'abbandona pas la physique du globe.

En 1924, pendant sa visite à Naples à l'occasion du Congrès des Sciences nous nous entretînmes sur l'opportunité d'instituer des recherches spectroscopiques et spectrographiques des flammes des volcans. Ensuite, pour plusieurs raisons, qu'il n'est pas le cas de mentionner ici, de telles mesures ne furent jamais exécutées. Pendant la dernière Assemblée d'Oslo de l'U. G. G. I., étant le Prof. LO SURDO président de la Délégation italienne, nous convînmes, que l'étude spectrographique des flammes volcaniques devrait être entreprise en Italie aussi, en grand et avec des appareils convenables. Il est à souhaiter que cette proposition soit recueillie et réalisée.

F. SIGNORE

L'Association Internationale de Volcanologie et le Bureau International de Volcanologie expriment leur vif regret pour la perte de ANTONINO LO SURDO à l'Institut National de Géophysique, à la Rédaction des « Annali di Geofisica », au Conseil National des Recherches Italien, à l'Université de Rome et à l'Accademia dei Lincei.

LA RÉDACTION

ALESSANDRO MALLADRA

(1865 - 1945 †)

Directeur honoraire de l'Observatoire Vésuvien, Professeur agrégé de Géographie Physique, ex-Secrétaire général de l'Association Internationale de Volcanologie de l'U. G. G. I.

MALLADRA obtint le diplôme de Docteur ès Sciences naturelles auprès de l' Université de Turin, en 1890, discutant la thèse: « Sul valore sistematico del Trifolium Ornithopodioides ».

Depuis le 1890 jusqu'au 1910, il enseigna Sciences naturelles dans le « Collegio Mellerio-Rosmini » de Domodossola. À cette époque à son activité scolastique il unit aussi la recherche scientifique.

Il établit dans l'Observatoire météorologique une station séismique, il suivit diligemment les travaux du tunnel du Simpion, en publiant d'importants articles et en créant le Musée de Sciences Naturelles avec la Salle Simpionienne. Dans les articles relatifs au tunnel du Simpion on trouve exposées des idées originales sur l'hydrographie souterraine, idées qui furent après confirmées. Entretemps il soigna l'édition des travaux d'ANTONIO STOPPANI: « Acqua ed Aria » et « Corso di Geologia », en y ajoutant des notes.

L'activité scientifique de MALLADRA, en ce temps-là, s'expliqua presque complètement dans l'étude des glaciers alpins.

En 1911, MERCALLI, Directeur de l'Observatoire Vésuvien, voulut MALLADRA comme son aide. De cette manière MALLADRA put réaliser son ancien désir: « far seguire allo studio dei ghiacciai alpini le ricerche e le osservazioni sul nostro classico vulcano ».

À la suite de la mort tragique du Directeur MERCALLI, le 19 mars 1914, le Prof. MALLADRA fut chargé de la direction de l'Observatoire Vésuvien, direction qu'il occupa jusqu'à l'achèvement du concours relatif. Le résultat du concours fut négatif, en tant que la Commision (1916) crut de ne pas proposer aucun des concurrents. Plusieurs candidats demandèrent la charge de la direction, mais le Ministère, d'après l'avis de la Faculté des Sciences de l'Université de Naples, confia de nouveau la direc-

tion au Professeur de Physique du Globe, Prof. CHISTONI, qui l'avait déjà eue dans l'intervalle entre la direction MATTEUCCI et la direction MERCALLI. Le Prof. CHISTONI confirma MALLADRA dans la place d'aide.

En 1923, la place de directeur fut supprimée et la direction technique et l'administration de l'Observatoire furent déférées à un Comité de Professeurs de l'Université de Naples, tandis que la charge de conservateur, instituée en même temps, fut occupée par MALLADRA. En 1927, ayant été rétablie la place de Directeur, MALLADRA, selon la proposition du Comité volcanologique, fut nommé Directeur.

Pendant sa direction il entreprit la publication de la 4e Série des « Annali del R. Osservatorio Vesuviano », qui est constituée par 3 volumes.

En 1935, A. MALLADRA prit sa retraite, ayant rejoint la limite d'âge.

En 1922, le Prof. MALLADRA fut élu Secrétaire général de l'Association Internationale de Volcanologie de l'U. G. G. I., et telle charge lui fut confirmée jusqu'à la Réunion d'Edimbourg, 1936, lorsqu'il présenta ses dimissions. Dans le triennat 1930-33 il fut Président de l'Association sans abandonner le Secrétariat.

Comme Secrétaire général de l'Association de Volcanologie il a dirigé la publication de 12 volumes du Bulletin Volcanologique.

La contribution du Prof. MALLADRA à la Volcanologie peut être relevée par ce que lui-même a écrit dans sa note « L'ascoltazione dei vulcani »:

" . . . . . l'Autore di queste pagine, giunto all'Osservatorio Vesuviano nel 1911, quale aiuto del Direttore MERCALLI, si propose l'osservazione continua, *giornaliera* e completa il più possibile dei fenomeni presentati dal Vesuvio.

" Egli tenne sempre presenti le parole di MONTICELLI e COVELLI: « Se uomini istruiti *vegliassero* in un *Osservatorio Meteorologico - vulcanico* a notare *tutte le vicende* del Vesuvio e ad osservare *tutti gli effetti* ch'esse producono nell'atmosfera, nel suolo e nel mare, . . . e se . . . attendessero a raccogliere, più ampiamente di quello che abbiamo potuto far noi, i numerosi prodotti ed edotti vulcanici di queste nostre regioni, . . . quale im-

menso vantaggio non ne trarrebbero l'Orittognosia e la Geologia! » (1), e fece sue quest'altre del PALMIERI: « potrò stimarmi contento se, data opera alla parte meteorologica, avrò potuto sorprendere i prodotti transitorii solidi od aeriformi facendone qualche saggio sopra luogo, ed in generale raccogliere i materiali ed i fatti meritevoli dell'attenzione dei naturalisti » (2).

" Egli venne all'Osservatorio quando era ancora in corso la fase di riposo del precedente periodo: ha assistito ai primi sintomi della ripresa di attività; era sull'orlo del cratere il giorno del risveglio (5 luglio 1913): ha seguito passo passo, giorno per giorno, fino al presente, (con circa *tremila escursioni* al cratere e dintorni, compiute in 24 anni di vita vesuviana) tutti i fenomeni dell' attività vulcanica, che condusse dapprima al totale riempimento della immane voragine creatasi nel 1906, poscia all'invasamento della Valle dell'Inferno, all'eruzione *a fontane* del giugno 1929 ed agli ulteriori fenomeni esplosivi ed effusivi che continuano tuttora.

* * *

" Le osservazioni che si compiono attualmente e *giornalmente* all'Osservatorio Vesuviano sono di varia natura:

" 1° *Osservazioni a distanza,* le quali si possono compiere da l'Osservatorio e anche da Napoli e da qualsiasi altro luogo da cui si scorge il vulcano; esse interessano tutti i sensi dell'uomo, ma specialmente la vista, l'udito e l'olfatto.

" Sono « *osservazioni visive* » quelle che riguardano la quantità e il colore dei fumi, la modalità della loro fuoruscita e, in servizio della meteorologia, anche la loro direzione: inoltre i materiali proiettati a grande altezza, oppure a distanza, data la tenuità del loro volume (ceneri, lapillo filiforme); ed ancora, i chiarori serali e notturni, dovuti a riverberi di esplosioni o di lave fluenti.

" Sono « *osservazioni acustiche* » quelle spettanti ai varii rumori provenienti dal cratere, come boati, esplosioni, rombare continuo come di lontana burrasca, spesso avvertiti non solo all'Os-

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(1) MONTICELLI e COVELLI. *Storia dei fenomeni del Vesuvio negli anni 1821, 1822 e 1823,* Napoli, 1823, p. XVII.

(2) *Annali del R. Osservatorio meteorologico vesuviano* compilati da L. PALMIERI. Vol. I, 1859, Proemio (in fine).

servatorio, ma anche in pianura, e che col progredire dell'attività diverranno via via più frequenti ed intensi. Un microfono sistemato nel fondo di un pozzo, che scende dodici metri sotto il piano del sotterraneo, permette di percepire i rumori che attraverso il suolo si propagano dal condotto vulcanico all'Osservatorio.

" Sono « *osservazioni olfattive* » quelle derivanti dagli odori dei gas che si espandono intorno e alla base del Gran Cono, in cui sono predominanti ora SO_2, ora HCl ed ora H_2S, e spesso misti fra di loro in tal modo da dare quello che si chiama comunemente « l'odore del cratere ».

" Ma non difettano nemmeno le « *osservazioni gustative e tattili* », dovute specialmente alle nevi salate e alle piogge caustiche che irritano fortemente le mucose, massime degli occhi. Quando si rimane per parecchie ore in fondo al cratere, i cloruri e i solfati che si depongono sulla pelle la rendono lubrica e come saponificata con sensazione di molteplici punture; tale lubricità pungente e fastidiosa si produce talvolta anche nei paraggi dell'Osservatorio, allorchè densi fumi rendono per parecchi giorni l'atmosfera caliginosa, per effetto dei venti di levante.

" 2°) *Osservazioni dal cratere*, che sono, come è ovvio, quelle derivanti dalle *escursioni quotidiane* che vengono compiute dal personale scientifico dell'Osservatorio e dai Carabinieri di servizio istruiti a tale scopo, per prendere diretta cognizione dell'attività intercraterica, dello stato del conetto eruttivo, dei fontanili o bocche di efflusso delle lave fluenti, della graduale sopraelevazione del fondo con formazione di cupole laviche, della topografia delle colate, ecc. Tali osservazioni, come le precedenti, sono giornalmente registrate in appositi quaderni, in modo che la storia dei fenomeni vesuviani riesce continua e completa quanto è possibile umanamente.

" 3°) *Osservazioni speciali*, sismiche, pirometriche, di radiazione penetrante, di radio-attività, di magnetismo, di elettricità atmosferica, ecc., per le quali nuovi e moderni apparecchi di ricerca sono stati acquistati coi fondi dell'Istituto e con aiuti generosamente largiti dal Banco di Napoli.

" L'osservazione continuativa della attività vesuviana mi ha condotto a confermare in parte le affermazioni del PALMIERI, del PERREY e di altri sulla reale influenza che la marea terrestre eser-

cita sopra i magma vulcanici, e quelle del De Lorenzo, dello Stella-Starabba e d'altri sopra l'azione d'incremento che deriva dalle precipitazioni atmosferiche sulla attività generale del vulcano. Inoltre, l'esame molte volte compiuto del modo con cui il conetto eruttivo principale si forma, cresce, si frattura, si distrugge e si riforma, in tempi di varia durata, mi ha permesso di ritrovarvi una perfetta analogia con quanto avviene, su ben più vasta scala, nel Gran Cono vesuviano; il che è di somma importanza per lo studio delle grandi fratture del nostro vulcano, da cui derivano gli efflussi laterali ed eccentrici.

" Un intero periodo vesuviano osservato giorno per giorno, come auspicava il sommo Palmieri, e studiato con gli stessi occhi e gli stessi criterii dal principio alla fine, sarebbe certamente di grandissimo interesse per la scienza in genere ed esuberante di buoni frutti per la vulcanologia ".

F. Signore

PUBLICATIONS

DU D.R ALESSANDRO MALLADRA

(1890 - 1936)

1. — *Sul valore sistematico del Trifolium Ornithopodioides.* (Tesi di laurea). Rivista « Malpighia », Vol. IV, fasc. IV. Genova, Tip. di Angelo Ciminago, 1890.
2. — (Con S. ROSSI) *Nozioni di Fisica, Chimica, Fisiologia umana ed Igiene,* (ad uso delle Scuole tecniche). Tip. L. F. Cogliati, Milano, 1892.
3. — *Ai confini d'Italia - Gries e Kaltwasser.* « Oscella » periodico mensile del Collegio Rosmini in Domodossola; N.° I. Tip. L. F. Cogliati, Milano, 1893.
4. — *Inaugurazione dell' Osservatorio* (di Domodossola). « Oscella », precitata, N.° I.
5. — *Il ghiacciaio di Macugnaga.* « Oscella », precitata, N.° 2.
6. — *Dinamica glaciale applicata ai ghiacciai ossolani.* « Oscella », precitata, N.° 3.
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14. — *Le acque minerali dell' Ossola.* « Oscella », precitata, N.° 11.
15. — *La fine dell'Ossola attuale e l'Ossola futura.* « Oscella », precitata, N.° 12.
16. — *Scene e paesaggi dell' Ossola antichissima.* Conferenza. Milano, Tip. L. F. Cogliati, 1894.
17. — *Acqua ed Aria* (di A. STOPPANI). 3.a edizione illustrata con note e aggiunte di A. MALLADRA. Milano, Tip. Cogliati. - Sono 50 note e l'aggiunta alla Conferenza VIIIa « *Il Mare d'Aral* », 1898.

18. — *Ai lavori del Sempione.* « Il Bene »; N.° di Natale 1898. Milano, Tip. L. F. Cogliati.

19. — *L'epoca glaciale nell'Ossola.* « In giro pel mondo », anno I, N. 19-20, Bologna, 1899.

20. — *Le antiche epoche geologiche nella valle d' Ossola.* « In giro pel mondo », anno 2, N. 1, Bologna, 1900.

21. — *Morfologia e Fisiologia vegetale.* (Lezioni di Storia Naturale per le scuole secondarie). Milano, Tip. L. F. Cogliati, 1900.

22. — *Corso di Geologia* di A. STOPPANI. 3.ª ediz. con note e aggiunte per cura di A. MALLADRA - Milano, Tip. Rebeschini di Turati. 3 volumi (*esaurito*), 1900.

Aggiunte al 1° Volume:

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23. — *L'acqua nel traforo del Sempione.* « Rassegna Nazionale » di Firenze; anno XXIII, Fasc. 480; 1.° dicembre. (Pubblicata pure a parte con illustrazioni e note). Milano, Tip. Cogliati, 1902.

24. — *Il Lago d'Avino.* « Il Buon cuore ». Milano, Tip. Cogliati, 1902.

25. — *Il traforo del Sempione.* Conferenza, con tavole e figure; (I ediz. 1904) II ediz. 1905, Milano, Tip. Cogliati.

26. — *Le sorgenti nel traforo del Sempione.* « Illustrazione italiana », Natale 1905, pag. 35; Treves, Milano.

27. — *Tromba marina nel Golfo di Vado.* Rivista di Fisica, Matematica e Scienze naturali; Pavia, Anno V, N.° 72, Dicembre 1905, Tip. Fusi.

28. — *Il Poiano.* « L'Ossola ed il Sempione ». Domodossola, Tip. ossolana, 1906.

29. — (con G. R. ENRICO) *La Sacra di S. Michele,* natura, arte e storia. Con 124 figure e 5 tav. fuori testo. Editore R. Streglio, Torino, 1907.

30. — *Il Bel Paese* di A. STOPPANI. I ediz. di lusso, con 1000 incisioni e con note di eminenti scienziati italiani, per cura di A. MALLADRA. - Milano, tip. Cogliati, 1908. (Le note aggiunte a questa edizione sono 292, di cui 132 del Malladra e 160 degli altri 28 annotatori).

31. — *Terremoti alla Sacra di S. Michele.* Contributo al catalogo dei terremoti italiani. Rivista di fis., mat. e sc. nat.; Pavia, anno IV, N.° 108, Dicembre 1908, Tip. Fusi.

32. — *Il terremoto di Sicilia studiato a Domodossola.* « Il Momento », Torino, 30 dicembre 1908.

33 — *La grande frattura Calabro-messinese secondo il Suess.* « Il Momento », Torino, 1° gennaio 1909.

34 — *La ressa delle onde sismiche contro le Alpi ossolane.* (A proposito del terremoto Calabro - messinese, 28 dicembre 1908). « L'avvenire dell'Ossola », N.° 1-7 gennaio, Domodossola, Tip. la Cartografica, 1909.

35. — *Scala delle distanze ad uso della Sismologia.* Boll. della Soc. Sism. Italiana, Vol. XIII, Modena, 1909.

36. — *Il sismogramma alpino del terremoto Calabro-messinese 28 dicembre 1908,* con tavola. Rivista di Fisica, Matematica e Scienze naturali, Anno X, N.° 110, febbraio, Pavia, Tipografia Fusi, 1909.

37. — *Notizie su l' Osservatorio geofisico Rosmini,* con figure. Domodossola, Tip. La Cartografica, 1910.

38. — *Le marmitte dei giganti in Val d'Ossola.* « L'Illustrazione ossolana », N.° 1, Domodossola, 1910.

39. — *Per il gran volo umano attraverso le Alpi.* « Il Momento », Torino, 8 agosto 1910.

40. — *La traversata delle Alpi in aeroplano e la meteorologia lepontina.* « Il Momento », Torino, 12 agosto 1910.

41. — *La gran via delle genti.* (Le gare aviatorie sempioniane). « Il Momento », Torino, 17 agosto 1910.

42. — *Il fondo del cratere vesuviano*. Rend. della R. Accad. delle Sc. Fis. e Mat. di Napoli; Fasc. 7.°, 8° e 9.°, luglio, agosto e settembre 1912.

43. — *Stato del Vesuvio*. (Genn.-Settem. 1913). Rivista di Vulcanologia, del Dott. I. FRIEDLAENDER. Vol. I., fasc. I, Berlino.

44. — *La Solfatara dell'Atrio del Cavallo*. Rend. della R. Acc. delle Sc. Fis. e Mat. di Napoli, Fasc. 6.° a 10.°, giugno a ottobre 1913.

45. — *Il terremoto, Napoli e il Vesuvio*. Rassegna Nazionale, Firenze, Novembre, fasc. I°, 1913.

46. — *Stato del Vesuvio* (Ottobre-Dicembre 1913). Rivista di Vulcanologia del Dott. I. FRIEDLAENDER. Vol. I°, fasc. 2°. Berlino.

47. — *Nel cratere del Vesuvio*. Boll. della R. Società geografica italiana, con molte figure e schizzi. Fasc. VII, 1914, pag. 753-805.

48. — *L' attività scientifica di G. Mercalli*. Rassegna Nazionale, Firenze, Novembre, fasc. I, 1914.

49. — *Sulle modificazioni del Vesuvio dopo il 1906 e la livellazione geometrica del vulcano*. Boll. della R. Soc. Geografica italiana, dicembre, fasc. XII, pag. 1237-1258, 1914.

50. — *La pioggia sul Vesuvio nel periodo 1863-1913*. Boll. della Soc. Sism. it., Vol. XVIII, fasc. 1-2, Modena, 1914.

51. — *I gas vulcanici e la vegetazione*. Boll. della Soc. Sism. it., Vol. XVIII, fasc. 3-4, Modena, 1914.

52. — *L'impianto sismico dell'Osservatorio Vesuviano*. Boll. della Soc. Sism. it., Vol. XVIII, fasc. 3-4, Modena.

53. — *Sui fenomeni successivi all' apertura della bocca 5 luglio 1913 nel cratere del Vesuvio*. Rend. della R. Acc. delle Sc. Fis. e Mat. di Napoli, Fasc. 11-12, novembre e dicembre 1914.

54. — *Necrologia di G. Mercalli*. Annuario R. Università degli Studi di Napoli per l'anno scolastico 1914-15.

55. — *Commemorazione di G. Mercalli*. Bollettino Soc. Naturalisti in Napoli, Vol. XXVIII (Serie II, Vol. VIII), Anno XXIX - Atti, pag. 31-48, 1915.

56. — (con C. CHISTONI) — *Singolare precipitazione acquea al Vesuvio*. Atti R. Acc. Lincei, Roma, Vol. XXVI, serie 5.ª, 1° sem. fasc. II, 1917.

57. — *Sopra l'attività del Vesuvio nell'aprile 1917* (con 1 tavola). Boll. della Soc. dei Naturalisti in Napoli, Vol. XXX (Serie II, Vol. X), Anno XXXI, Atti, pag. 36-47, 1917.

58. — *Sopra due proietti calcarei dell'eruzione vesuviana di aprile 1906*. Rend. R. Acc. delle Sc. Fis. e Mat., Serie 3.ª, XXIII, Napoli, 1917.

59. — *Grotta di scolamento lavico negli efflussi vesuviani del 1858*. Boll. Soc. dei Naturalisti in Napoli, Vol. XXX, (Serie II, Vol. X), Anno XXXI, Atti, pag. 109-123, 1917.

60. — *Rapporto al Prof. CIRO CHISTONI: Sulla pioggia torrenziale e sulla grandine del giorno 6 di giugno 1918*. R. Acc. delle Sc. Fis. e Mat. di Napoli, Serie 3.ª, Vol. XXIV, 1918.

61. — *Riassunto sull'attività del Vesuvio nel 1917*. Boll. della Soc. dei Naturalisti in Napoli, Vol. XXXI, (Serie II, Vol. XI), Anno XXXII, 1918. Atti, pag. 132-163.

62. — *Temperature di lave fluenti nel cratere del Vesuvio*. Rend. R. Acc. Sc. Fis. e Mat. di Napoli, Serie 3.ª, Vol. XXV, 1919.

63. — *Temperature di lave fluenti nel cratere del Vesuvio, misurate il 29 settembre 1920*. Rend. R. Acc. Sc. Fis. e Mat di Napoli, Serie 3.ª, Vol. XXVII, 1921.

64. — *L'attività del Vesuvio nel 1918*. Boll. Soc. dei Natur. in Napoli, Vol. XXXIV, (Serie II, Vol. XIV, Anno XXXV, 1921, Atti, pag. 69-127.

65. — *Sul graduale riempimento del cratere vesuviano* (con tre carte e una tavola). Atti VIII° Congresso geogr. ital., Istituto Fratelli Alinari, Firenze, Vol. II, 1922.

66. — *Sulle temperature di una corrente lavica nel cratere del Vevio misurate il 28 febbraio 1922 e sull'attività del vulcano nello stesso mese*. Rend. R. Acc. delle Sc. Fis. e Matem. di Napoli, Serie 3.ª, Vol. XXVIII, 1922.

67. — *Il termo-gradiente verticale Napoli-Vesuvio*. Atti R. Istituto d'incoraggiamento di Napoli, 1922.

68. — *Temperature di gas incandescenti nel cratere del Vesuvio*. Rend. R. Acc. Sc. Fis. e Mat. di Napoli, Serie 3.ª, Vol. XXVIII, 1922.

69. — *Etna, Vulcano e Stromboli nell'estate 1921* (con tavole e figure). Tip. Giannini, Napoli, 1922.

70. — *Vulcani, vulcanismo e vulcanologia*. La Lettura, 1° agosto, Anno XXIII, N. 8, Tip. del Corriere della Sera, Milano, 1923.

71. — *Proietti fiammogeni nel cratere del Vesuvio*. Rend. R. Acc. Naz. dei Lincei, Cl. Scienze Fis., Mat. e Natur., Vol. XXXII, Serie 5.ª, 2° sem., fasc. II, Roma, 1923.

72. — *La vita del Vesuvio* (con 13 figure). Rivista illustrata del Popolo d'Italia, Anno II, N. 6, giugno 1924. Milano.

73. — *Bulletin volcanologique*, organe de la Section de Volcanologie de l'Union Géodésique et Géophysique internationale; publié par le Secrétaire Général de la Section : A. MALLADRA. — I^{e} Année, N.^{os} I.^{r} et II.^{e}, 1924, Tip. Franc. Giannini e Figli, Napoli.

74. — *Osservazioni e ricerche su l'attuale periodo vesuviano*. Boll. Volc., année 1924, N.° I.

75. — *Rapport du Secrétaire Général* A. MALLADRA : *Sur le mode de fonctionnement du Bureau central de Volcanologie à Naples*. Bull. Volc., 1924, N.° I, p. 119.

76. — *Annibale Riccò*. Necrologia. Bull. Volc., 1924, N.° I.

77. — *Cartografia antica e vulcanologia*. Bull. Volc., N.° 2, 1924.

78. — *Bulletin Volcanologique*. 2^{e} année, N.^{os} 3-4 et 5-6, 1925.

79. — *L'attività del Vesuvio nel 1924* (con 4 fig. e una cartina nel testo e 8 tavole). Annali del R. Osservatorio Vesuviano, Serie 3.^{a}, Vol. I, Unione Tipografica Combattenti, Napoli, 1925.

Lo stesso in francese, Bull. Volc., N. 3-4, 1925.

80. — *Breakages of Telegraphic Cables and other Submarine Phenomena due to Seismo-volcanic Action*. Bull. Volc., N.° 3-4, 1925.

81. — *L'attività del Vesuvio nel 1925* (con 5 tavole e 2 figure nel testo). Annali del R. Osservatorio Vesuviano, Serie 3.^{a}, Vol. II, Anno 1925, Tip. Napoletana Giulio de Georgio, Napoli.

Lo stesso in francese, Bull. Volc., N.° 9-10, 1926.

82. — *Bulletin Volcanologique*, 3^{e} année, N.^{os} 7-8, 9-10, 1926.

83. — *Il pianto del Vesuvio*. « La Tribuna », 15 gennaio 1926, Roma.

84. — *Procès verbaux des Séances de la Section de Volcanologie dans la II^{e} Assemblée Générale de l'Union Géodésique et Géophysique Internationale* (Madrid, 1-8 octobre 1924). Bull. Volc., N.° 7-8, 1926.

85. — *Il Vesuvio dal 1906 al 1920*. 1^{a} puntata del volume 1° e 1^{a} puntata del vol. 2°; 216 pp. in 4°, con figure e 69 tavole fuori testo. Napoli, Tip. Cimmaruta, 1926.

86. — *Il Professore Ciro Chistoni e l'Osservatorio Vesuviano*. Annali del R. Osservatorio Vesuviano, Serie 3.^{a}, Vol. III, Anno 1926, Tipografia Napoletana di G. de Georgio, Napoli.

87. — *Studi recenti sul Vulcanismo*. Atti della Società Italiana per il progresso delle Scienze, XV^a riunione, Bologna, 31 ottobre-5 novembre 1926. Tip. Successori Frat. Fusi, Pavia, 1927.

88. — *In memoria di Giuseppe Mercalli* (Commemorazione). Rivista di Fisica, Matematica e Scienze Naturali, Vol. 1.^{0} (2^a Serie), p. 445-469. Napoli, Tip. dei Combattenti, 1927.

89. — *Bulletin Volcanologique*, 4^e année, N.^{os} 11-12, 1927.

90. — *Le livellazioni di precisione del Vesuvio nel 1913 e 1927*. Bull. Volc., 4^e année, N.^{os} 11-12, 1927.

91. — *Rapport du Secrétaire Général de la Section de Volcanologie à la III^e Assemblée Générale de l'Union Géodésique et Géophysique internationale* (Prague, 1-10 septembre 1927). Bull. Volc., 4^e année, N.^{os} 11-12, 1927.

92. — *Phases of the recent eruption of Vesuvius*. The Illustrated London News, 22 June 1929, London.

93. — *Carta del Vesuvio*, scala 1 : 25000, 1930.

94. — *Nuove osservazioni intorno alla pioggia sul Vesuvio*. Atti XI Congr. Geog. Ital., Vol. II, Napoli 1930.

95. — *Guida della escursione al Vesuvio*. Atti XI Congr. Geog Ital., Vol. IV, Napoli 1930.

96. — *Le recenti eruzioni vesuviane ed in particolare quella del giugno 1929*. Atti Soc. Ital. Progr. Sc., XIX riun., Bolzano-Trento, 7-15 settembre 1930, Vol. I^0, Roma 1931.

97. — *Les raz de marée ou tsunamis dans le Golfe de Naples*. Ann. de la Comm. pour l'Étude des Raz de Marée, N^0 1, Librairie Larose, Paris 1931.

98. — *Bulletin volcanologique*, 4^e année, N.^{os} 13-14, 1931.

99. — *Annali del Reale Osservatorio Vesuviano*. Serie 4^a, Vol. I, per gli anni 1927-1928, Tip. F. Giannini e Figli, Napoli 1932.

100. — *Prefazione agli Annali del Reale Osservatorio Vesuviano*. Annali del Reale Osservatorio Vesuviano, Serie 4^a, Vol. I^0. 1932.

101. — *Ferruccio Zambonini*. Annali del Reale Osservatorio Vesuviano, Serie 4^a, Vol. I^0, 1932.

102. — *Bulletin volcanologique*, 5^e année, N.^{os} 15-18, 1933.

103. — *Notices de phénomènes géodynamiques communiquées au Bureau central international de Volcanologie*. Bull. Volc., 5^e année, N.^{os} 15-18.

104. — *Bulletin Volcanologique*, 6^e année, N.^{os} 19-22, 1933.

105. — *L'éruption vésuvienne du 3-8 Juin, 1929*. Bull. Volc., 6e année, N.os 19-22.

106. — *Sur l'activité actuelle du Vésuve*. Bull. Volc., 6e année, N.os 19-22.

107. — *Relazione sull'attività svolta dal R. Osservatorio Vesuviano nel 1929-1930*. Boll. del Comit. Nazionale italiano per la Geodesia e la Geofisica, Serie IIa, Anno I°, N° 6, Firenze 1931.

108. — *Le eruzioni catastrofiche del Vesuvio*. Pubblicazioni della Commiss. ital. per lo studio delle grandi calamità. R. Acc. Naz. Lincei, Vol. III, Roma 1933.

109. — (in coll. con C. A. KTÉNAS). — *Sur l' opportunité que les Comités nationaux des Pays où se trouvent des volcans actifs envoient chaque année des rapports sur les phénomènes relatifs au Bureau C. I. de Volcanologie à l'Observatoire du Vésuve. — Sur la création d'un catalogue mondial détaillé des Volcans actifs de la terre*. Bull. Volc., 6e année, N.os 19-22, 1933.

110. — *Procès-Verbaux des Séances de la Section de Volcanologie. - Quatrième Assemblée générale de l'U.G.G.I. Stockholm, 1930*. Bull. Volc., 6e année, N.os 19-22.

111. — *Annali del R. Osservatorio Vesuviano*. Ser. 4a, Vol. II, 1929-1930, Napoli 1934.

112 — *Le ricerche vulcanologiche in Italia durante il periodo 1930-1933*. Annali del R. Osservatorio vesuviano, Ser. 4a, Vol. II, 1929-1930, Napoli 1934.

113. — *Escursione Napoli-Vesuvio*, 2a Ed., Napoli 1933.

114. — *Bulletin volcanologique*, 7e année, N.os 23-26, 1934

115. — *Notice nécrologique*. Bull. volc., 7e année, N.os 23-26.

116. — *Annali del Reale Osservatorio Vesuviano*. Ser. 4a, Vol. III, 1931-1932, Napoli 1935.

117. — *L'ascoltazione dei vulcani*. (Conferenza di classe tenuta nella XXIII Riunione della Società Italiana per il progresso delle Scienze, Napoli 1934). Annali del R. Osservatorio Vesuviano, Ser. 4a, Vol. III, 1931-1932, Napoli 1935.

118. — *Bulletin volcanologique*, 8e année, N.os 27-30, 1936.

119. — *Allocution du Président Malladra pour l'ouverture de l'Assemblée de l'Association de Volcanologie à Lisboa*. Bull. Volc., 8e année, N.os 27-30.

120. — *La costituzione interna della Terra*. « Scientia », Anno 30°, Luglio 1936. Zanichelli, Bologna 1936.

SOMMAIRE